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ICES ADVISORY COMMITTEE

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Report of the Working Group on Widely Distributed Stocks (WGWIDE)

27 August - 2 September 2013

ICES Headquarters, Copenhagen, Denmark

ICES
International Council for the Exploration of the Sea
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Executive Summary

The Working Group (WG) on Widely Distributed Stocks (WGWIDE) met at ICES HQ in Copenhagen , Denmark, from 27 August to 2 September 2013. The meeting was attended by 30 delegates from Netherlands, Ireland, Spain, Norway, Portugal, Iceland, United Kingdom (England and Scotland), Faroe Islands, Denmark, Russia and Germany. Other fisheries scientists participated by correspondence. The WG reports on the status and considerations for management of northeast Atlantic mackerel, blue whiting, western and North Sea horse mackerel, northeast Atlantic boarfish and Norwegian spring spawning herring stocks.

Analyses were also conducted for one special request pertaining to the historic catch data used in the assessment of NEA mackerel.

Northeast-Atlantic (NEA) Mackerel. This species is widely distributed through the ICES area and currently supports one of the most valuable European fisheries. Mackerel is fished by a variety of fleets from many countries (ranging from open boats using hand lines on the Iberian coasts to large freezer trawlers and Refrigerated Sea Water (RSW) vessels in the Northern Area. The WG has previously raised concerns that the quality of data available for the assessment of this stock is disproportionately poor in relation to the status of this fishery and the importance of the stock in the ecosystem it inhabits. Landings data are unreliable and discarding information is scarce. Work done in relation to a special request from NEAFC (Annex 3) confirms that the current ICA assessment is sensitive to the likely levels of misreporting of catches in the past.

While the WG notes that much effort is being put into attempting to find and create new sources of data that can inform the management of the stock (for example the development of a swept area index of the Nordic seas) it was decided that the current assessment of the stock is not of sufficient quality to be used as a basis for advice on future fishing opportunities. Hence, only exploratory analytical assessments were conducted for this stock. Attempts were made by the group to use the only currently accepted fisheries independent data series for this stock (the MEGS survey, with a new preliminary triennial value available for 2013) in the ICES DLS approach. However, the group could not come to a unanimous decision on the final advised catch. Annex 6 of this report details the reasoning behind the rejection of the ICA assessment and provides points for consideration of the ADG and ACOM for the final decisions on the advice for 2014 for this stock.

Blue whiting. This is a pelagic gadoid that is widely distributed in the eastern part of the North Atlantic. The assessment this year was considered an update. The assessment revealed that the year classes 2005-2008 are among the lowest observed, but indications from various regional surveys show that recruitment in recent years is likely much higher. SSB has declined sharply since the early 2000s, but the current assessments suggest a continuation of the increase in SSB observed last year. Fishing mortality in 2012,while up from 2011, remains below precautionary and management plan reference points. The reference points for this stock were revised following new simulation work conducted for a management strategy evaluation for this stock (WKBWNSSH, March 2013).

Western Horse Mackerel. The WG performed an analytical assessment for western horse mackerel following the benchmark procedure. Following the MEGS survey a new preliminary triennial SSB estimate was available for this stock. The inclusion of

this new data lead to a significant downward revision in the estimated SSB of the stock. This was matched with a corresponding increase in the estimate of mean F for the stock. In the absence of any notably large recent year classes, SSB is perceived to be declining and is near the lowest observed level. The current outlook for the coming years suggests that this decline will continue.

North Sea horse mackerel. New exploratory data analyses were conducted for the North Sea horse mackerel stock. Following recommendations from WGWIDE 2012, improvements were made to the procedure used to derive an index of abundance for this stock from IBTS (Q3) data. However, the new index derived has not yet be meaningfully incorporated into a full analytical assessment model and does not change the perception of the stock compared to last year. Indications remain that the SSB of the stock is at a low level.

Northeast Atlantic Boarfish. This is a small, pelagic, planktivorous, shoaling species, found at depths of 0 to 600 m. The species is widely distributed from Norway to Senegal. The fishery for boarfish in the NEA is a new one, and hence landings of boarfish have showed a sharp increase in recent years. This year an analytical assessments was accepted for this stock for the first time. The 2012 and 2013 acoustic survey data were considered reliable, but there is high uncertainty in the estimates of total biomass due to the short time-series. Bottom-trawl survey indices were considered indicative of trends in their respective areas.

Estimates suggest that fishing mortality is below F_{MSY}, and the stock is likely not overfished. The assessment is still sensitive to the inclusion of data from the acoustic survey given the short time series currently available. Total stock biomass is estimated to be approximately 1 million tons in 2012, declining in 2013. Survey data suggests that recruitment has increased from that observed until 2005.

Norwegian spring spawning herring. This is the largest herring stock in the world. It is highly migratory and distributed throughout large parts of the NE Atlantic. The assessment was performed using the assessment tools software TASACS (benchmarked in 2008). An updated algorithm was implemented to derive the terminal fishing mortalities on the oldest age groups in the assessment for cohorts where there is insufficient information to estimate these. The new algorithm has increased the retrospective stability in the assessment. Even though F has been decreasing in recent years, in the absence of any strong year classes since 2004, the stock has declined still further in 2013. SSB at the start of 2013 is estimated to be at Bpa. This decline is expected to continue in the near future even when fishing according to the management plan, though it is expected that following the management plan will lead to the stock stabilising above Blim.

1 Introduction

1.1 Terms of Reference

2012/2/ACOM15 The **Working Group on Widely Distributed Stocks** (WGWIDE), chaired by David Miller, The Netherlands, will meet in ICES HQ, Denmark, 27 August to 2 September 2013 to:

a) Address generic ToRs for Regional and Species Working Groups (see table below).

The assessments will be carried out on the basis of the stock annex in National Laboratories, prior to the meeting. This will be coordinated as indicated in the table below.

WGWIDE will report by 9 September 2013 for the attention of ACOM.

Fish Stock	Stock Name	Stock Coord.	Assess. Coord. 1	Assess. Coord. 2	Advice
boc-nea	Boarfish in the Northeast Atlantic	Ireland			Update
her-noss	Herring in the Northeast Atlantic (Norwegian spring-spawning herring)	Norway	Norway	Russia	Update
hom-nsea	Horse mackerel (*Trachurus trachurus*) in Division IIIa, Division IVb,c and VIId (North Sea stock)	Spain	Netherlands	UK (England & Walse)	Multiyear
hom-west	Horse mackerel (*Trachurus trachurus*) in Divisions IIa, IVa, Vb, VIa,, VIIa-c, e-k, VIIIa-e (Western stock)	Spain	UK (England & Wales)	Netherlands	Update
mac-nea	Mackerel in the Northeast Atlantic (combined Southern, Western and North Sea spawning components)	Ireland	Netherlands	UK (Scotland)	Update
whb-comb	Blue whiting in Subareas I-IX, XII and XIV (Combined stock)	Spain	Denmark	Russia	Update

In addition to these specific requests to WGWIDE the group is also tasked with addressing generic ToRs described below for each of the stocks where appropriate:

a) If no stock annex is available this should be prepared prior to the meeting, based on the previous year advice basis or on the data limited advice basis proposed as the basis for advice this year.

b) Audit the assessments and forecasts carried out for each stock under consideration by the Working Group and write a short report.

c) Propose specific actions to be taken to improve the quality and transmission of the data (including improvements in data collection).

d) Propose indicators of stock size (or of changes in stock size) that could be used to decide when an update assessment is required and suggest threshold % (or absolute) changes that the EG thinks should trigger an update assessment on a stock by stock basis.

e) Consider target categories for stocks in the medium term as proposed and revise as needed

f) Consider ecosystem overviews where available, and propose and possibly implement incorporation of ecosystem drivers in the analytical basis for advice

g) For the ecoregion or fisheries considered by the working group, produce a brief report summarising for the stocks and fisheries where the item is relevant:

   i) Mixed fisheries overview and considerations;

   ii) Species interaction effects and ecosystem drivers;

   iii) Ecosystem effects of fisheries;

   iv) Effects of regulatory changes on the assessment or projections;

h) Prepare planning for benchmarks next year, and put forward proposals for benchmarks of integrated ecosystem, multi or single species for 2015

i) Draft the required elements of the Popular Advice for each stock.

j) In the autumn, where appropriate, check for the need to reopen the advice based on the summer survey information and the guidelines in AGCREFA (2008 report). The relevant groups will report on the AGCREFA 2008 procedure on reopening of the advice before 14 October and will report on reopened advice before 29 October.

For <u>update</u> advice stocks:

k) Produce a first draft of the advice on the fish stocks and fisheries under considerations according to ACOM guidelines and implementing the generic introduction to the ICES advice (Section 1.2). If no change in the advice is needed, one page 'same advice as last year' should be drafted.

l) For each stock , when possible prior to the meeting:

   i) Update, quality check and report relevant data for the stock:

      1) Load fisheries data on effort and catches (landings, discards, bycatch, including estimates of misreporting when appropriate) in the INTERCATCH database by fisheries/fleets, either directly or, when relevant, through the regional database. Data should be provided to the data coordinators at deadlines specified in the ToRs of the individual groups. Data submitted after the deadlines can be incorporated in the assessments at the discretion of the Expert Group chair;

      2) Abundance survey results;

      3) Environmental drivers.

   ii) Produce an overview of the sampling activities on a national basis based on the INTERCATCH database or, where relevant, the regional database,

   iii) Update the assessment using the method (analytical, forecast or trends indicators) as described in the stock annex.

   iv) Produce a brief report of the work carried out regarding the stock, summarising for the stocks and fisheries where the item is relevant:

1. Input data (including information from the fishing industry and NGO that is pertinent to the assessments and projections);
2. Where misreporting of catches is significant, provide qualitative and where possible quantitative information and describe the methods used to obtain the information;
3. Stock status and catch options for next year;
4. Historical performance of the assessment and brief description of quality issues with the assessment;
5. In cooperation with the Secretariat, update the description of major regulatory changes (technical measures, TACs, effort control and management plans) and comment on the potential effects of such changes including the effects of newly agreed management and recovery plans. Describe the fleets that are involved in the fishery.

m) On basis of the outcomes of WKMSYREF calculate Fmsy for stocks where the information exists but the calculations have not been done yet, resolve inconsistencies between Fmsy and MSY $B_{trigger}$/Blim and if possible, fill in the Precautionary Approach reference points where they are missing

For re-examine advice stocks

n) Consider the advice for 2013 and review data and/or method to ascertain if there is reason to update advice for 2014.

   i) Where an update is required, revert to an update procedure
   ii) Where no advice update is required, produce a brief report of the work carried out regarding the stock, indicating why the advice is not updated. A one page, 'same advice as last year' should be drafted.

For stocks with multiyear advice or biennial 2nd year advice

o) In principle, there is no reason to update this advice. The advice should be drafted as a one page version referring to earlier advice. If a change in the advice (basis) is considered to be needed, this should be agreed by the working group on the first meeting day and communicated to the ACOM leadership. Agreement by the ACOM leadership will revert the stock to an update procedure.

1.2 List of participants

WGWIDE 2013 was attended by 30 delegates from Netherlands, Ireland, Spain, Norway, Portugal, Iceland, United Kingdom (England and Scotland), Faroe Islands, Denmark, Russia and Germany. Other fisheries scientists participated by correspondence. The full list of participants is in Annex 1.

1.3 Quality and Adequacy of fishery and sampling data

Sampling Data from Commercial Fishery

The working group again carried out a brief review of the sampling data and the level of sampling on the commercial fisheries. Sampling coverage for mackerel is 89%, in comparison to last year the proportion of the horse mackerel catch sampled increased from 62% to 71% but is still low with only a limited number of countries providing data. Norwegian spring spawning herring and blue whiting sampling covers 93% and 80% of the total catch, respectively. Following the memory of understanding agreement between the EU and ICES boarfish (*Capros aper*) was included into WGWIDE since 2011 and tables on the sampling level for this species are added in this section.

In general, to facilitate age-structured assessment, samples should be obtained from all countries with catches of the relevant species.

The sampling programmes on the various species are summarised as follows:

Mackerel

Year	TOTAL CATCH (wg catch)	% catch covered by sampling programme*	No. samples	No. Measured	No. Aged
1992	760,000	85	920	77,000	11,800
1993	825,000	83	890	80,411	12,922
1994	822,000	80	807	72,541	13,360
1995	755,000	85	1,008	102,383	14,481
1996	563,600	79	1,492	171,830	14,130
1997	569,600	83	1,067	138,845	16,355
1998	666,700	80	1,252	130,011	19,371
1999	608,928	86	1,109	116,978	17,432
2000	667,158	76	1,182	122,769	15,923
2001	677,708	83	1,419	142,517	19,824
2002	717,882	87	1,450	184,101	26,146
2003	617,330	80	1,212	148,501	19,779
2004	611,461	79	1,380	177,812	24,173
2005	543,486	83	1,229	164,593	20,217
2006	472,652	85	1,604	183,767	23,467
2007	579,379	87	1,267	139,789	21,791
2008	611,063	88	1,234	141,425	24,350
2009	734,889	87	1,231	139,867	28,722
2010	869,451	91	1,241	124,695	29,462
2011	938,819	88	923	97,818	22,817
2012	892,762	89	1,216	135,610	38,365

***Percentage related to working group catch.**

Sampling activity increased in 2012 after a drop in 2011, in particular the total number of fish aged. The proportion of the working group catch sampled was 89%, in line with previous years. It should be noted that this figure is based on the total sampled catch and thus the largest catching nations that can sample 100% of their catch mask any deficiencies at national level and with more widely dispersed fisheries. This is especially true when a large proportion of the total catch is taken in large, directed fisheries which are relatively straightforward to sample.

Denmark, Faroe, Iceland, Ireland, Norway, Portugal, Russia, Scotland and Spain all sampled over 95% of their catch. As in previous years, England & Wales sampled a small fraction of their total catch, corresponding to the handline fishery in area VIIe. The freezer trawler fleet operating out of the Netherlands, Germany, England and France is covered by the Dutch and German sampling programs as the fleet is principally Dutch-owned. Individual samples within this fishery consist of only 25 aged fish which can be limiting when only a single sample is available in a particular area and quarter. In particular, there is a lack of sampling activity in the fourth quarter for this fleet. The Dutch program also provided samples for English registered freezer trawlers landing into the Netherlands. Of the remaining countries with significant catches Northern Ireland, Greenland and Sweden did not provide any sampling information. France conducted length-frequency sampling but no ageing was carried out.

The sampling summary of the mackerel catching countries is shown in the following table:

COUNTRY	OFFICIAL CATCH	% catch covered by sampling programme*	NO. SAMPLES	NO. MEASURED	NO. AGED
Belgium	39	0	0	0	0
Denmark	36,501	99	19	1,657	1,657
Faroe Islands	107,630	100	16	1,659	1,621
France	20,467	-	-	15,790	0
Germany	18,944	41	40	21,291	873
Greenland	5,284	0	0	0	0
Guernsey	5	0	0	0	0
Iceland	149,282	98	215	10,387	8,325
Ireland	63,049	95	61	10,205	1,795
Isle of Man	11	0	0	0	0
Netherlands	25,817	65	35	3,125	875
Norway	176,023	100	356	15,319	4,959
Portugal	824	99	51	2,451	398
Russia	74,587	100	92	28,948	799
Spain	19,386	98	249	15,138	15,097
Sweden	4,564	0	0	0	0
UK (England & Wales)	19,187	32	43	4,565	701
UK (Northern Ireland)	14,945	0	0	0	0
UK (Scotland)	135,602	96	39	5,075	1,265
Total	872,147	89	1,216	135,610	38,365

*** Percentage based on Working Group catch,**

- unknown

The following table describes the mackerel sampling intensity levels in terms of catch in each ICES division. Areas where insufficient sampling was carried out include all of area III, IVc, VIIId and some subdivisions of VII. This has been the case for some of these areas for several years although the unsampled areas represent a small fraction of the total catch.

AREA	OFFICIAL CATCH	WG CATCH	NO SAMPLES	NO AGED	NO MEASURED	NO AGED/ 1000 TONNES*	NO MEASURED / 1000 TONNES*
IIa	281,691	281,691	279	4,558	41,932	16	149
IIb	6	6	0	0	0	0	0
IIIa	613	615	0	0	0	0	0
IIIb	3	3	0	0	0	0	0
IIIc	1	1	0	0	0	0	0
IIId	1	1	0	0	0	0	0
IVa	215,307	215,534	250	5,118	11,221	24	52
IVb	2,026	2,314	8	200	811	99	400
IVc	451	473	0	0	0	0	0
Va	130,184	130,184	169	5,165	6,665	40	51
Vb	23,693	23,693	8	839	860	35	36
VIa	121,114	121,122	68	2,118	16,278	17	134
VIIa	25	25	0	0	0	0	0
VIIb	24,561	26,587	31	713	9,252	29	377
VIIc	2,240	2,947	2	50	84	22	38
VIId	6,132	6,139	9	225	807	37	132
VIIe	829	866	3	75	372	90	449
VIIf	325	325	31	198	3,659	609	11,258
VIIg	3	680	0	0	0	0	0
VIIh	396	1,318	0	0	0	0	0
VIIj	24,893	31,235	29	873	7,025	35	282
VIIIa	2,166	2,166	1	25	70	12	32
VIIIb	2,178	2,178	19	477	1,227	219	563
VIIIcE	17,618	17,618	173	4,328	10,737	246	609
VIIIcW	4,577	4,577	27	5,146	1,198	1,124	262
VIIId	1,972	1,972	0	0	0	0	0
IXaN	1,484	1,512	30	5,146	1,976	3,468	1,332
IXaCN	827	1,591	51	398	2,451	481	2,964
IXaS	434	1,303	0	0	0	0	0
XIVb	11,633	11,633	28	2,713	3,195	233	275

*** Based on official catches**

Horse Mackerel

The following table shows a summary of the overall sampling intensity on horse mackerel catches in recent years in all areas 1992-2009 and in the western and North Sea areas for the following years. The Southern horse mackerel is now dealt with by ICES WGHANSA.

Year	TOTAL CATCH (wg catch)	% catch covered by sampling programme*	No. samples	No. Measured	No. Aged
1992	436,500	45	1,803	158,447	5,797
1993	504,190	75	1,178	158,954	7,476
1994	447,153	61	1,453	134,269	6,571
1995	580,000	48	2,041	177,803	5,885
1996	460,200	63	2,498	208,416	4,719
1997	518,900	75	2,572	247,207	6,391
1998	399,700	62	2,539	245,220	6,416
1999	363,033	51	2,158	208,387	7,954
2000	272,496	56	1,610	186,825	5,874
2001	283,331	64	1,502	204,400	8,117
2002	241,336	72	1,768	235,697	8,561
2003	241,830	79	1,568	200,563	12,377
2004	216,361	68	1,672	213,066	16,218
2005	234,876	78	2,315	241,629	15,866
2006	215,277	72	1,623	231,344	12,009
2007	187,995	62	1,321	174,897	10,749
2008	198,085	77	1,362	186,800	11,915
2009	247,637	87	1,258	92,846	13,345
2010	224,462	78	703	48,465	13,984
2011	222,415	62	502	40964	7604
2012	169,859	71	478	37001	7645

*** Percentage related to Working Group catch**

The large numbers of measured fish 1922-2009 were due to intensive length measurement programs in the southern areas. In 2008, 76% of the horse mackerel measured were from Division IXa.

Countries that usually carried out sampling were Ireland, the Netherlands, Germany, Norway and Spain and they covered 18-97% of their respective catches. In 2012 Germany, Ireland, the Netherlands, Norway, UK (England) and Spain provided samples and age distributions. The lack of sampling data for relatively large portions of the horse mackerel catches continues to have a serious effect on the accuracy and reliability of the assessment and the Working Group remain concerned about the low number of fish that are aged.

The horse mackerel sampling intensity for the Western stock in 2012 was as follows:

COUNTRY	OFFICIAL CATCH	% CATCH SAMPLED*	NO. SAMPLES	NO. MEASURED	NO. AGED
Belgium	0		0	0	0
Denmark	4002		0	0	0
France	1795		0	0	0
Germany	17063	36%	21	3563	416
Ireland	45311	94%	38	5797	2083
Netherlands	66396	66%	35	5039	875
Norway	3251	96%	24	975	747
Spain	13560	82%	334	17669	2874
UK (England)	12122	76%	26	3958	650
UK(Scotland)	1335	0%	0	0	0
Total	164835	71%	478	37001	7645

* Percentage based on Working Group catch

The horse mackerel sampling intensity for the North Sea stock in 2012 was as follows:

COUNTRY	OFFICIAL CATCH	% CATCH SAMPLED*	NO. SAMPLES	NO. MEASURED	NO. AGED
Belgium	47	0	0	0	0
Denmark	1514	0	0	0	0
France	1048	0	0	0	0
Germany	5256**	0	0	0	0
Ireland					
Netherlands	12157	80%	21	3790	525
Norway	129	0	0	0	0
Sweden					
UK (England)	936	92%	2	357	50
UK (Scotland)	240	0	0	0	0
Total	21597	49%	23	4147	575

* Percentage based on Working Group catch

** including 170.5 t in IIIc

The horse mackerel sampling intensity by division was as follows:

Area	Official Catch	WG Catch	N samples	N aged	N measured	N aged per 1000t	N measured per 1000t
IIa	66	66	0	0	0	0	0
IIIa	9	9	0	0	0	0	0
IIIc	170	-*	0	0	0	0	0
IVa	3312	3666	24	747	975	204	266
IVb	515	158	0	0	0	0	0
IVc	1430	1430	4	100	746	70	522
VIa	44973	44971	29	1573	4388	35	98
VIb	69	-*	0	0	0	0	0
VIIb	36792	36792	20	627	2428	17	66
VIIc	10550	10550	4	100	414	9	39
VIId	19481	19480	19	475	3401	24	175
VIIe	12319	12318	39	975	7861	79	638
VIIf	1	1	0	0	0	0	0
VIIg	87	87	0	0	0	0	0
VIIh	4409	4409	4	100	920	23	209
VIIj	36384	39424	23	624	2247	16	57
VIIk	519	519	1	25	99	48	191
VIIIa	1639	1639	0	0	0	0	0
VIIIb	5337	3410	46	170	1877	50	550
VIIIcE	4308	5985	171	1753	11305	293	1889
VIIIcW	4060	6367	117	951	4487	149	705
VIIId	1	1	0	0	0	0	0
VIIIe	0	0	0	0	0	0	0
Total	186431	191283	501	8220	41148	43	215

* Not compiled by InterCatch

Norwegian Spring Spawning Herring (NSSH)

Year	TOTAL CATCH	% catch covered by sampling programme	No. samples	No. Measured	No. Aged
2000	1,207,201	86	389	55956	10901
2001	766,136	86	442	70005	11234
2002	807,795	88	184	39332	5405
2003	789,510	71	380	34711	11352
2004	794,066	79	503	48784	13169
2005	1,003,243	86	459	49273	14112
2006	968,958	93	631	94574	9862
2007	1,266,993	94	476	56383	14661
2008	1,545,656	94	722	81609	31438
2009	1,686,928	94	663	65536	12265
2010	1,457,015	91	1258	124071	12377
2011	992.997	95	766	79360	10744
2012	825.999	93	649	59327	14768

93% of the total catch was covered by national sampling programmes. The following table gives a summary of the sampling activities of the NSSH catching countries. The sampling coverage by country is between 73 and 100%. No sampling was carried by the Netherlands, Scotland, Greenland and Sweden representing together 2.5% of the total catch.

COUNTRY	OFFICIAL CATCH	% catch covered by sampling programme	NO. SAMPLES	NO. MEASURED	NO. AGED
Denmark	21.753,83	100%	12	1523	586
Faroe Islands	36.190,00	99%	16	1559	1525
Germany	11.944,85	88%	10	3763	192
Greenland	1.490,00	0%	0	0	0
Iceland	120.956,00	73%	166	8598	3873
Ireland	4.812,25	100%	2	242	100
Netherlands	6.237,05	0%	0	0	0
Norway	491.005,00	100%	271	15488	6939
Russia	118.595,00	100%	172	28154	1553
Scotland	12.310,43	0%	0	0	0
Sweden	705,00	0%	0	0	0
Total for Stock	825.999,44	93%	649	59327	14768

Shown in the following table are the NSSH sampling levels by relating numbers measured and aged to the size of the catch in each ICES division.

Area	Official Catch	WG Catch	No Samples	No Aged	No Measured	No Aged/1000	No Measured/1000
IIa	657424	657424	446	10450	36542	16	56
IIb	83964	83964	80	399	15110	5	180
IVa	9640	9640	10	773	777	80	81
Va	67372	67372	103	2341	5329	35	79
Vb	5692	5692	8	682	729	120	128
XIVa	1906	1906	2	123	840	65	441
Total	825998	825998	649	14768	59327	18	72

*** Based on official catches**

Blue Whiting

Year	TOTAL CATCH	% catch covered by sampling programme	No. samples	No. Measured	No. Aged
2000	1,412,928	*	1136	125162	13685
2001	1,780,170	*	985	173553	17995
2002	1,556,792	*	1037	116895	19202
2003	2,321,406	*	1596	188770	26207
2004	2,377,569	*	1774	181235	27835
2005	2,026,953	*	1833	217937	32184
2006	1,966,140	*	1715	190533	27014
2007	1,610,090	87	1399	167652	23495
2008	1,246,465	90	927	113749	21844
2009	635,639	88	705	79500	18142
2010	524,751	87	584	82851	16323
2011	103,591	85	697	84651	12614
2012	373,937	80	1143	173206	15745

* no figures given

80% of the total catch was covered by national sampling programmes which is the lowest coverage of the last six years. The sampling summary of the blue whiting catching countries is shown in the following table. No sampling was carried out by Denmark, France, Germany and the UK (England and Scotland) representing together 6,5% of the total catches (Denmark: 0,09%, France 2,62%, Germany 1,67%, UK 2,11%).

COUNTRY	OFFICIAL CATCH	% catch covered by sampling programme	NO. SAMPLES	NO. MEASURED	NO. AGED
Denmark	340	0	0	0	0
Faroe Islands	43289	92	13	1345	1278
France	9798	0	0	0	0
Germany	6238	0	0	0	0
Iceland	63056	93	21	1932	1200
Ireland	7557	74	7	1446	702
Netherlands	26525	75	75	12656	1874
Norway	118832	78	530	21855	3439
Portugal	1956	90	20	1641	384
Russia	81725	91	323	52470	3314
Spain	6726	76	154	79861	3554
UK(England)	1590	0	0	0	0
UK(Scotland)	6305	0	0	0	0
Total	373937	80	1143	173206	15745

The following table describes the blue whiting sampling levels by relating numbers measured and aged to the size of the catch in each ICES division.

Area	Official Catch	No Samples	No Aged	No Measured	No Aged/ 1000 tonnes*	No Measured/ 1000 tonnes*
IIa	21277	609	3405	40432	160	1900
IIb	161	50	460	7356	2857	45689
IIIa	15	0	0	0	0	0
IVa	5618	0	0	0	0	0
IVb	45	0	0	0	0	0
IXa	3453	20	384	1641	111	475
Va	2930	2	82	132	28	45
Vb	131541	107	2043	18168	16	138
VIa	91965	87	2652	7999	29	87
VIb	11865	5	502	1041	42	88
VIIb	16040	35	455	5059	28	315
VIIc	65501	73	2109	11412	32	174
VIIg	4294	0	0	0	0	0
VIIh	180	0	0	0	0	0
VIIIa	559	0	0	0	0	0
VIIIb	399	0	0	0	0	0
VIIIc	4696	154	3554	79861	757	17006
VIIId	695	0	0	0	0	0
VIIj	966	0	0	0	0	0
VIIk	10662	0	0	0	0	0
XII	1053	1	100	105	95	100
XIVa	4	0	0	0	0	0
XIVb	18	0	0	0	0	0
Total	373937	1143	15746	173206	42	463

* Based on official catches

Boarfish

Year	TOTAL CATCH	% catch covered by sampling programme	No. samples	No. Measured	No. Aged
2001	120	0	0	0	0
2002	91	0	0	0	0
2003	11387	0	0	0	0
2004	5151	0	0	0	0
2005	5959	0	0	0	0
2006	7137	0	0	0	0
2007	21576	NA	3	217	0
2008	34751	NA	1	152	0
2009	90370	NA	9	1 475	0
2010	144047	NA	95	10 675	403*
2011	37096	NA	27	4 066	704
2012	87355	NA	80 (68)***	9 656 (8 565)***	814**

*A common ALK was developed from fish collected from both commercial and survey samples. This comprehensive ALK was used to produce catch numbers at age data for pseudo-cohort analyses.

**A common ALK was developed from fish collected from samples from Danish, Irish and Scottish commercial landings. This comprehensive ALK was used for all métiers to produce catch numbers-at-age data for pseudo-cohort analyses. Only aged fish measured to 0.5cm were included in the ALK.

*** This is the combined Irish and Danish total samples. The numbers in parentheses are the Irish samples excluding the Danish samples. There were a number of data quality issues which are outlined in section 6.2. Therefore only Irish collected samples were used for length frequency.

COUNTRY	OFFICIAL LANDINGS (excluding discards)	% landings covered by sampling programme	NO. SAMPLES	NO. MEASURED	NO. AGED
Denmark	19 888	NA	12	1 091	171*
Ireland	55 949	NA	68	8 565	425*
UK(Scotland)	4 884	0	0	0	218*
Total	80 720	NA	80	9 656	814*

*All samples were aged at DTU-Aqua by the same age reader and method as per the 2010 and 2011 samples.

Area	Official Landings	No Samples	No Aged	No Measured	No Measured/ 1000 tonnes*
VIa	125	1 (1)*	0	96 (96)*	768
VIIb	5 419	3 (3)*	30	339 (339)*	63
VIIc	1 015	0	0	0	
VIIg	616	0	0	0	
VIIh	19 554	17 (12)*	615	2222 (1627)*	114 (83)
VIIj	52 294	57 (52)*	169	6785 (6503)*	130 (124)
VIIIa	1 697	2	0	214	126
Total	80 720	80 (68)*	814	9656 (8565)*	120 (106)

* This is the combined Irish and Danish total samples. The numbers in parentheses are the Irish samples excluding the Danish samples. There were a number of data quality issues which are outlined in section 6.2. Therefore only Irish collected samples were used for length frequency.

Catch Data

Recent working groups have on a number of occasions discussed the accuracy of the catch statistics and the possibility of large scale under reporting or species and area misreporting.

The working group considers that the best estimates of catch it can produce are likely to be underestimates.

In the case of mackerel unreported catches in the time-series were identified as major reason for the “underestimation of stock size in the analytical assessment, which is the basis of the scientific advice. The level of misreporting may have changed over time. This will remain a problem for future years, as the model cannot compensate for an unknown level of historical unreported catches" (ICES Advice 2012, Book 9, pg. 9). A special request on this issue was considered by WGWIDE 2013 and is dealt with in Annex 03 of this report.

Discards

Discarding in pelagic fisheries is more sporadic than in demersal fisheries. This is because the nature of pelagic fishing is to pursue schooling fish, creating hauls with low diversity of species and sizes. Consequently, discard rates typically show extreme fluctuation (100% or zero discards). High discard rates occur especially during ´slippage´ events, when the entire catch is released. The main reasons for ´slipping´ are daily or total quota limitations, illegal size and mixture with unmarketable bycatch. Quantifying such discards at a population level is extremely difficult as they vary considerably between years, seasons, species targeted and geographical region.

Discard estimates of pelagic species from pelagic and demersal fisheries have been published by several authors. Discard percentages of pelagic species from demersal fisheries were estimated between 3% to 7% (Borges *et al.*, 2005) of the total catch in weight, while from pelagic fisheries were estimated between 3% to 17% (Pierce *et al.* 2002; Hofstede and Dickey-Collas 2006, Dickey-Collas & van Helmond 2007, Ulleweit & Panten 2007, Borges *et al*. 2008, van Helmond *et al*. 2009, 2010 and 2011). Slipping estimates have been published for the Dutch freezer trawler fleet only, with values at around 10% by number (Borges *et al*. 2008) and around 2% in weight (van Helmond *et al*. 2009, 2010 and 2011) over the period 2003-2010. Nevertheless, the majority of these estimates were associated with very large variances and composition estimates of ´slippages´ are liable to strong biases and are therefore open to criticism.

Borges *et al*. (2008) show that for the Dutch freezer trawler fleet between 2002 and 2005, the most important commercial species discarded is mackerel, accounting for 40% of total pelagic discards. Other important discarded species are herring (18%), horse mackerel (15%) and blue whiting (8%). These discards are also the consequence of fisheries targeted at other species (*e.g.* mackerel in the horse mackerel and herring targeted fisheries). Boarfish was found to account for 5% of the discards. Total amount of discards by species in this fleet were estimated by van Helmond *et al*. (2009, 2010 and 2011) for the years 2003-2011. They indicate that discards in these years for blue whiting (3%; range 1-15%), herring (3%; range 1-7%) and horse mackerel (1%; range 1-5%) are low, but higher for mackerel (25%; range 16-37%). Dutch-owned freezer-trawlers also operate in European waters under German, UK, and French flags.

Because of the potential importance of significant discarding levels on pelagic species assessments the **Working Group again recommends that observers should be placed on board vessels in those areas in which discarding occurs, and existing observer programmes should be continued. Furthermore agreement should be made on sampling methods and raising procedures to allow comparisons and merging of dataset for assessment purposes.**

Mackerel

The Netherlands, Spain, Germany, Ireland, Denmark and Portugal provided discard data on mackerel to the working group. Age disaggregated data was only available from Spain and Portugal which indicate that the discarded catch is dominated by age 0 and 1 fish. For 2012 the total mackerel discards reported were 15,380 t. The working group considers this to be an underestimate (see section 2.3.1) and the discard sampling to be incomplete.

Horse Mackerel

In the past discards of juvenile horse mackerel have been thought to constitute a problem. However, in recent years a targeted fishery has developed on juveniles, including 1-year old fish and discarding of juveniles is now thought to be small. Over the years the Netherlands, Germany, Ireland and Spain have provided discard data. However, based on these data it is impossible to estimate the total discard rate in the horse mackerel fishery, since the discard rates reported are quite different. In 2012 discard data were available from Spain and the Netherlands. Germany and Ireland observed zero discard during observed trips.

Norwegian Spring Spawning Herring

The Working Group has no comprehensive data to estimate discards of herring. Although discarding may occur on this stock, it is considered to be very low and a minor problem to the assessment. This is confirmed by estimates from sampling programmes carried out by some EU countries in the Data Collection Framework. Estimates on discarding in 2008 and 2009 of about 2% in weight were provided for the trawl fishery carried out by the Netherlands. In 2010 and 2012, this metier was sampled by Germany. No discarding of herring was observed (0%).

The Norwegian coast guard maintains a close presence with the pelagic fishing fleet in Norwegian waters with several vessels and a plane. IMR has a co-operation with a number of reference vessels in the pelagic fleet, primarily for the purposes of biological sampling but also recording losses through gear damage or slipping. These data indicate that the frequency of slipping and the total quantities of fish slipped are low and, although the quantity remains unknown, are too small to have a significant effect on the reliability of the assessment.

Blue Whiting

Discards of blue whiting are thought to be small. Estimates from the DCF discard sampling programme carried out by the Netherlands on pelagic trawlers in 2008, 2009, 2010 are 3%, 1% and 4% in weight respectively. In 2011 the estimate shows a distinct higher rate with 15%. Most of these discards are by-catch in fisheries not directed to blue whiting. In directed fisheries most of the blue whiting is caught for reduction purposes. New data on Spanish discards in the blue whiting fishery were available this year.

Boarfish

Discard data were available from Dutch and German pelagic freezer trawlers and from Irish, Spanish and Portuguese demersal fleets for the period 2003-2012. The Portuguese data relate to Division IXa and are not relevant to this stock. Discards were not obtained from UK or French freezer trawlers, though discard patterns in these fleets are likely to be similar to the Dutch fleet. It is to be expected that discarding occurred before 2003, in demersal fisheries, however it is difficult to predict what the levels may have been.

Age-reading

Reliable age data are an important pre-requisite in the stock assessment process. The accuracy and precision of these data, for the various species, is kept under constant review by the Working Group.

Mackerel

A Workshop on Age Reading of Mackerel (WKARMAC) met in November 2010 to review, assess and recommend on the state of quality in mackerel otolith based age estimation.

Inter-calibration between readers and labs were performed before the workshop. The overall result of the exchange and workshop exercise was that there were significant variations in mackerel age estimates between readers. Low precision, and large relative biases between readers were found, and the older ages (from age 6) were particularly difficult to reach agreement upon.

The workshop achieved quite a lot in terms of ironing out, through discussion and calibration, some of the major problems in ageing otoliths of mackerel, such as interpreting patterns close to the margin, split rings and differences between areas and through time. The group reached agreement on a set of ageing guidelines that are given in the WKARMAC report. Furthermore, a collection of agreed age otoliths have been established.

Inter-calibration between readers and labs were also performed after the workshop. Agreement rates with the modal age ranged from 71.7% to 85.1%. This compares favorably with the pre-workshop exchange (44.9% to 77.4%). The bias scores show a range from -0.30 to +0.22, with an overall bias of +0.01. Again this compares well to the pre-workshop exchange (-0.59 to +0.45). The overall results showed that the meeting had improved the performance of the reader-group.

WKARMAC recommended that WGWIDE carry out an analysis of acceptable variance around the estimated proportions at age for mackerel. In response to this a working document was prepared for the 2011 WGWIDE meeting: "Influence of ageing errors on the NEA Mackerel assessment outputs" (Brunel 2011, see Section 10 of the 2011 WGWIDE report) It was concluded that ageing errors result in misestimating the size of cohorts, with strong (weak) recruitments being underestimated (overestimated). The error on the initial size of a cohort propagates through the estimated numbers at age matrix. As positive errors on a cohort tend to be compensated by negative (and vice versa) errors on the adjacent cohorts, the overall effect on the SSB is limited. Errors on Fbar4-8 were larger, due to associated to errors in the selectivity pattern estimated by ICA.

A small scale otolith exchange for mackerel is scheduled for late 2013.

Horse mackerel

A Workshop on age reading of horse mackerel (*Trachurus trachurus*), Mediterranean horse mackerel (*Trachurus mediterraneus*) and blue jack mackerel (*Trachurus picturatus*) (WKARHOM) exchanged information by correspondence in 2011 and met in April 2012 to review information on age determination, compare different otolith-based age determination methods, identify sources of age determination error, provide specific guidelines for the interpretation of growth structures in otoliths, create a reference collection and data base of otolith images, and address the generic ToRs adopted for workshops on age calibration.

A total of 25 scientists and technicians, from 11 laboratories in 8 countries (France, Germany, Ireland, Italy, Norway, Portugal, Romania and Spain) participated in the workshop. For the assessment of the sources of age determination error, 16 age readers participated in the otolith exchange, 7 of the institutions read sectioned otoliths, 3 read whole otoliths, 2 read broken burnt whole otoliths and 3 read sectioned otoliths and whole otoliths. There were 10 sets of images of *Trachurus trachurus*, *T. mediterreaneus* and *T. picturatus*, from Ireland, North Spain, South Spain, Azores, Mauritania and Adriatic Sea. Percentage of agreement ranged from 36% to 67% for different otolith sets. The effect of otolith preparation techniques on age determination showed significant differences between readers and between otolith preparation methods, and also showed that the differences between methods were not the same across age readers. There were differences in interpretation primarily in the old individuals, with estimated age from sliced otoliths being higher than estimated age from whole otoliths.

A selection of 30 otoliths from horse mackerel (n = 23), Mediterranean horse mackerel (n = 5) and blue jack mackerel (n = 2) were selected for the reference collection. All otoliths for the reference collection were chosen by the most experienced readers during the workshop and covered an age span from 0 to 18 years old. Ages were agreed on by all participants. The main achievements of the workshop were the inclusion, for the first time, of *T. picturatus* and *T. mediterraneus*, a review on current otolith preparation and lab procedures, a quantification of disagreement between readers, the clarification of different ageing criteria previously used, an agreement on common criteria for ageing, the update of an ageing manual, and the assembling of an otolith reference collection for future use. Therefore, WKARHOM has set the basis for training of new readers and future improvement on otolith reading agreement. A follow-up workshop, to be chaired by Teresa Garcia (Spain) and Alba Jurado (Spain), was proposed to exchange information by correspondence in 2014 and meet in Sta. Cruz de Tenerife (Canary Islands, Spain), 26-30 October 2015.

Norwegian Spring Spawning Herring

A scale and otolith exchange of Norwegian spring spawning herring took place in 2007-2008. Otolith and scale samples of Norwegian spring spawning herring (NSSH) from the ecosystem survey in the Nordic seas in May were provided by the Institute of Marine Research, Norway. Four countries were participating in the scale and otolith exchange; Norway, Faroe Islands, Iceland and Denmark. Norway and Iceland estimated the ages by reading scales, and Faroe Islands and Denmark estimated the ages by reading the otoliths.

Based on results from this scale and otolith exchange, the age estimate of NSSH between the four countries is very similar. High precision were obtained, and there were no relative bias between different countries. Precision of age estimates appears to be a little higher for the two countries reading scales compared to the two countries reading otoliths, but this is also influenced by technical aspects of the order the different readers are placed in the EFAN-spreadsheet. There is therefore no evidence for difference in the age estimates as a consequence of reading scales versus otoliths.

Another recent comparison (Couperus 2008) of age readings from scales and otoliths for Norwegian spring spawning herring from 2 samples taken at the ASH survey in 2008 also indicates no indication that there is any difference in performance between age readings from scales and otoliths. Scales were read by readers from Denmark, otoliths by readers from the Netherlands.

A small scale otolith exchange for Norwegian spring spawning herring is scheduled for late 2013.

Blue Whiting

A workshop (WKARBLUE) on age reading of blue whiting (*Micromesistius poutassou*) took place in Bergen, Norway, from 10–14 June 2013 chaired by Jane Amtoft Godiksen and Manuel Meixide.

A sample of 158 otoliths was annotated by the participants previously to the meeting, using WebGR, and a sub-sample of 50 of them was re-annotated at the meeting. Two new samples from Faeroes and Russia of 50 otoliths each were available at the meeting, together with pictures that were uploaded to WebGR.

The overall agreement obtained in the workshop were very poor in all samples with the exception of the Faroese one, showing that biased readings were present in many cases, even in experienced readers.

During the workshop an online reference collection was agreed and uploaded to the WebGR server at Azti (http://webgr.azti.es/) and to the European Age Readers Forum (EARF). Also an Ageing Manual was created, containing General Guidelines for Age Determination. A report on the outcomes of the workshop will be available soon.

Biological Data

Some problems in relation to other biological data were identified by the Working Group. It was noted that for north east Atlantic mackerel there is inadequate sampling for stock weights during the spawning season (see section 2.4.2). All other stocks did not report any specific issues regarding biological data.

Quality Control and Data Archiving

Current methods of compiling fisheries assessment data

Information on official, area misreported, unallocated, discarded and sampled catches have again this year been recorded by the national laboratories on the WG-data exchange sheet (MS Excel; for definitions see text table below) and sent to the stock co-ordinators or uploaded on the WGWIDE SharePoint. Co-ordinators collate data using the latest version of *sallocl* (Patterson, 1998) which produces a standard output file (*Sam.out*). However only sampled, official, WG catch and discards are available in this file. Efforts were made to use the Intercatch system this year in parallel to the existing system (see Sec.1.3.8 for details).

There are at present no defined criteria on how to allocate samples of catch numbers, mean length and mean weight at age to unsampled catches, but the following general process is implemented by the species co-ordinators. Searches are made for appropriate samples by gear (fleet), area, and quarter. If an exact match is not available the search will move to a neighbouring area, if the fishery extends to this area in the same quarter. More than one sample may be allocated to an unsampled catch, in this case a straight mean or weighted mean of the observations may be used. If there are no samples available the search will move to the closest non-adjacent area by gear (fleet) and quarter, but not in all cases. For example, in the case of NEA mackerel samples from the southern area are not allocated to unsampled catches in the western area. It would be very difficult to formulate an absolute definition of allocation of samples to unsampled catches which was generic to all stocks, however full documentation of any allocations made are stored each year in the data archives (see below). It was noted that when samples are allocated the quality of the samples may not be examined (i.e. numbers aged) and that allocations may be made notwithstanding this. The Working Group again encourages national data submitters to provide an indication of what data could be used as representative of their unsampled catches. Definitions of the different catch categories as used by the WGWIDE:

Official Catch	Catches as reported by the official statistics to ICES
Unallocated Catch	Adjustments (positive or negative) to the official catches made for any special knowledge about the fishery, such as under- or over-reporting for which there is firm external evidence.
Area misreported Catch	To be used only to adjust official catches which have been reported from the wrong area (can be negative). For any country the sum of all the area misreported catches should be zero.
Discarded Catch	Catch which is discarded
WG Catch	The sum of the 4 categories above
Sampled Catch	The catch corresponding to the age distribution

Quality of the Input data

Primary responsibility for the accuracy of national biological data lies with the national laboratories that submit such data. Each stock co-ordinator is responsible for combining, collating, and interpolating the national data where necessary to produce the input data for the assessments. A number of validation checks are already incorporated in the data submission spreadsheet currently in use, and these are checked by the co-ordinators who in the first instance report anomalies to the laboratory which provided the data.

The working group acknowledges the effort some members have made to provide “corrected” data, which in some cases differ significantly from the officially reported catches. Most of this valuable information is gathered on the basis of personal knowledge of the fishery and good relations between the responsible scientist and the fishermen. The WG is aware of the problem that this knowledge might be lost if the scientist resigns, and asks the national laboratories to ensure continuity in data provision. In addition the working group recognises and would like to highlight the inherent conflict of interest in obtaining details of unallocated catches by country and increasing the transparency of data handling by the Working Group.

Overall, data quality has improved and sampling deficiencies have been reduced compared to earlier years, partly due to the implementation of the EU sampling regulation for commercial catch data. However, some nations have still not or inadequately aged samples. Others have not even submitted any data, so only catch data from Eurostat are available, which are not aggregated quarterly but are yearly catch data per area. Sampling deficiencies are documented by the data transmission tables which were filled in by the stock coordinators. These tables can be found on the WGWIDE SharePoint.

The Working Group documents sampling coverage of the catches in two ways. National sampling effort is tabulated against official catches of the corresponding country (section 1.3.1). Furthermore, tables showing total catch in relation to numbers of aged and measured fish by area give a picture of the quality of the overall sampling programme in relation to where the fisheries are taking place. These tables are shown in section 1.3.1 as text tables under the species sections.

Transparency of data handling by the Working Group and archiving past data

The national data on the amount and the structure of catches and effort are archived in the ICES Intercatch database. The data are provided directly by the individual countries and are highly aggregated for the use of stock assessments. In the past three years ICES maintained records of submission, use, quality and relevance of data, use of data in assessment provided by the individual countries, named as "Data Tables". The intention of this information was to fulfil ICES' obligations as a scientific organisation to make the data used in the assessment fully transparent but also to comply with ICES' obligations to the EU. These data were also used by the EC to evaluate whether EU member states have complied with EU data regulations and have submitted the data to ICES. It was decided by ICES that no data tables are supplied in 2013.

The subject of transmission of data to ICES and other end-users has been discussed by STECF in 2011 (STECF PLEN 11-02 and STECF EWG 11-08) in the context of the introduction of regional data bases (RDB) to support international co-operation in data collection by EU member states. The RDBs are now nearly implemented. STECF and ICES expects that the RDBs will develop rapidly and that in the near future it will be possible to use the RDB to aggregate data accommodating the data needs of end-users like ICES. The STECF EWG has presented a roadmap for the expected transmission routes and procedures for the submission of data by EU member states to ICES. The roadmap aims for submission of member state data to ICES through the RDB from 2014 onwards.

In recent years, ICES has implemented a Sharepoint solution for the storage and sharing of working group data and documentation. In addition, a shared folder is usually made available to working group participants for the duration of the meeting. Traditionally, stock data was stored in a folder called 'archives' on this shared disk. Upon completion of the meeting the folder is backed up and maintained by ICES. This is problematic for group members who wish to view historic data. **The WG recommends that an equivalent structure on the Sharepoint point be established for the storage of such data and that ICES communicates this clearly to the stock and assessment coordinators and that access to all historic sharepoint sites in their original form be maintained. Consideration should also be given to making the data and working documents from meetings where no Sharepoint site was available accessible to members of WGWIDE.**

The WG continues to ask members to provide any kind of national data reported to previous working groups (official catches, working group catches, catch-at-age and biological sampling data), to fill in missing historical disaggregated data. However, there was little response from the national institutes. **The WG recommends that national institutes increase national efforts to gain historical data, aiming to provide an overview which data are stored where, in which format and for what time frame.** The Working Group still sees a need to raise funds (possibly in the framework of a EU-study) for completing the collection of historic data, for verification and transfer into digital format. This is particularly relevant given that for the 2005 mackerel assessment the time series had to be truncated due to poor data in the earliest years.

Stock data problems relevant to data collections

A number of other stock data problems were brought forward to the contact person and are listed in Annex 05 for the information of ICES, RCMs and PGCCDBS.

The Spanish authority for the Data Collection Framework is the Fisheries General Secretary (SGP). Last year there were strict instructions for using only these official data, and not the landing estimates provided by the Spanish research institutes IEO and AZTI. This year, after several meetings with the Spanish authority, the official Spanish data will be used but this would be modified if the scientific estimates were considered as better data source. However, given that the official data are based on VMS, log-book and auction sheets information whilst the scientific estimates are mainly based on harbour-landing data, any discrepancy between both sources of data should remain as unallocated.

InterCatch

Acceptance test of InterCatch

All stock coordinators should make sure that catch data are imported into InterCatch and use InterCatch, following the Generic Terms of Reference. InterCatch is the standardised documentation system for stock assessment expert groups and a part of the ICES Quality Assurance Program. Therefore it is suggested that stock coordinators request national data submitters to import catch data into InterCatch over the internet in the InterCatch format to ease the stock coordinators work. If stock coordinators have not used, tested and compared the output from InterCatch with the so far used system, it is suggested that it is done in 2013. Stock coordinators should verify that InterCatch fulfils the needs of their stocks and gives the expected output. Hereby the stock coordinator can also approve InterCatch as the system, which can be use in the future.

Table of Use and Acceptance of InterCatch				
Stock code for each stock of the expert group	InterCatch used as the: 'Only tool' 'In parallel with another tool' 'Partly used' 'Not used'	If InterCatch have not been used what is the reason? Is there a reason why InterCatch cannot be used? Please specify it shortly. For a more detailed description please write it in the 'The use of InterCatch' section.	Discrepancy between output from InterCatch and the so far used tool: Non or insignificant Small and acceptable significant and not acceptable Comparison not made	Acceptance test. InterCatch has been fully tested with at full data set, and the discrepancy between the output from InterCatch and the so far used system is acceptable. Therefore InterCatch can be used in the future.
mac-nea	Only tool			Can be used
her-noss	Not used	Because the program SALLOC was used to provide catches in numbers	Comparison not made	InterCatch have not been properly tested
hom-nsea	Only tool		Comparison not made	Can be used
hom-west	Only tool		Non or insignificant	Can be used
whb-comb	Only tool	InterCatch was used last years		Can be used

1.4 Comment on update and benchmark assessments

For this year, ICES had scheduled update assessments for Blue Whiting, Norwegian Spring Spawning Herring, Western horse mackerel and NEA Mackerel. A new assessment was available for boarfish (not yet benchmarked) and for the North Sea horse mackerel data explorations were undertaken and some simple HCRs were examined (no accepted assessment for this stock).

1.4.1 Latest benchmark results

There were no new benchmark assessments for the stocks in WGWIDE in 2013.

1.4.2 Planning future benchmarks

A new benchmark assessment will be worked on at WKPELA in October 2013 and February 2014.

1.5 Special Requests to ICES

A special request regarding historic mackerel catch estimates was given to the group by NEAFC: "***ICES is requested to explore and evaluate the sensitivity of the current assessment to past uncertainties in the estimates of removals.***"

It was decided at by the group to provide a simple sensitivity analysis to evaluate the potential impacts of historic under reporting of catches. The results of this work are provided in Annex 3 of this report. The results show that if current catch estimates (since 2005) are more accurate than historic estimates, then the model is likely to be over-estimating F in the recent period relative to the past.

The results presented should not be assessed in a qualitative way since absolute estimates of historic misreporting could not be obtained. It should also be noted that different assessment model utilising different data sources may not treat historic catches in exactly the same manner. Hence the degree of impact of historic misreporting is likely to vary between assessment models.

Work done on this request is likely to be taken further during the benchmark process.

1.6 Ecosystem considerations for widely distributed and migratory pelagic fish species

It has been known for more than a century that ecosystem factors have a determinant effect on the productivity of fish stocks, and may therefore be a source of variation as important as exploitation by fisheries. Various biological aspects of fish stocks such as recruitment, growth or natural mortality, are influenced by ecosystem factors (Skjoldal *et al*. 2004). Geographical distribution of stocks and species migration patterns may also vary according to environmental conditions (Sherman and Skjoldal 2002). Ecosystem factors influencing fish stocks include:

Physical (temperature, salinity) conditions
Hydrographical (turbulence, stratification) conditions
Large scale circulation patterns
Inter-species and intra-species relationships
Bottom-up effect of zooplankton on pelagic fishes
Competition for food or space between pelagic species
Top-down control of pelagic species by predator abundance

An important challenge for the future meeting of this working group will be to take ecosystem considerations into account in stock assessment methods in order to reduce levels of uncertainty regarding the status and prediction of stocks. WGWIDE encourages further work to be carried out on ecosystem considerations linked to widely distributed fish stocks including NEA mackerel, Norwegian spring-spawning herring, blue whiting and horse mackerel. Emphasis should be on how ecosystem considerations from scientific studies and knowledge may be implemented and applied for management considerations.

Climate variability and climate change

Climate, in its wider sense, refers to the state of the atmosphere, for instance in terms of partitioned air masses (IPCC 2001; 2007). Climate variability, caused by the variations of atmospheric characteristics around the average climatic state, occurs via recurrent and persistent large-scale patterns of pressure and circulation anomalies. The North Atlantic Oscillation (NAO) is the recurrent pattern of variability in circulation of air masses over the North Atlantic region, corresponding to the alternation of periods of strong and weak differences between Azores high and Icelandic low pressure centers. Variations in the NAO influence winter weather over the North Atlantic (storm track, precipitations, strength of westerly winds) and hence have a strong impact on oceanic conditions (sea temperature and salinity, Gulf Stream intensity, wave height). Since 1996 the Hurrell winter NAO index has been fairly weak but mainly positive, except for during 2001, 2004 and 2006 (ICES, 2007). The Iceland Low and the Azores High were both weaker than normal in 2007 and 2008, and the centre of the Iceland Low was displaced towards the southwest to the entrances to the Labrador Sea (ICES 2007, 2008, 2009). The 2011 winter NAO index was negative although not as low as 2010 but lower than the long-term average (1950–2010). Hence, favourable winds supporting a strong Atlantic influence in the waters west of the British Isles and other regions continued to be lower than during high NAO years.

Accumulation of anthropogenic greenhouse gases in the atmosphere is currently effecting climate change (IPCC 2001; 2007). The classical measure of global warming is the Northern Hemisphere Temperature anomaly (NHT) (Jones and Moberg, 2003) which is computed as the anomaly in the annual mean of sea water and land air surface temperature over the northern hemisphere. Since the early 1900s, a warming of the northern hemisphere is evident. A first period of increasing temperature occurred from the early 1920s to about 1945. The period from the 1950s to the middle of the 1970s, corresponded to a light decrease of the NHT. During the last three decades, NHT anomalies have exhibited a strong warming trend. Many fish species are long-lived and therefore the effects of oceanographic conditions may be buffered at the population scale and integrated over time, even at the individual scale (Tasker *et al*. 2008). Nevertheless, pelagic planktivorous species such as northeast Atlantic mackerel, Norwegian spring-spawning herring and blue whiting may take advantage of warming ocean ecosystems expending possible feeding opportunities, through increasing their geographical distribution area, e.g. in Arctic waters.

Circulation pattern

Large-scale circulation patterns set the stage for important processes influencing fish species and ecosystems covered by WGWIDE. The circulation of the North Atlantic Ocean is characterized by two large gyres: the *subpolar gyre* (SPG) and *subtropical gyre* (Rossby, 1999). When the SPG is strong it extends far eastwards bringing cold and fresh subarctic water masses to the NE Atlantic, while a weaker SPG allows warmer and more saline subtropical water to penetrate further northwards and westwards over the Rockall plateau area. Changes in the oceanic environment in the Porcupine/Rockall/Hatton areas have been shown to be linked to the strength of the subpolar gyre (Hátún *et al.*, 2005). In recent years the area has been dominated by the warmer and more saline Eastern North Atlantic Water (Hátún *et al.*, 2007). The large oceanographic anomalies in the Rockall region spread directly into the Nordic Seas, regulating the living conditions there as well as further south. Such changes are likely to have an impact on the spatial distribution of spawning and feeding grounds and on migration patterns of certain pelagic species.

Temperature

Temperature is well known to affect many aspects of fish biology, such as recruitment, growth, or mortality rates. Temperature affects fish both directly – through its effect on metabolic rates affecting growth and energy requirements - and indirectly – through its effect on the production of prey items and production and distribution of predators.

Feeding and spawning distributions and migration patterns of widely distributed species are also closely related to temperature: the timing of migration can be triggered by temperature and migration routes are related to temperature gradients (Harden Jones 1968; Leggett 1977). A better understanding of these effects could provide valuable information for both assessment and management of widely distributed stocks.

Time-series of sea surface temperature (SST) and salinity for the North Atlantic show generally rising trends in the recent years. An increasing trend in temperature and salinity was observed in the upper ocean during the period from 1996-2008 (ICES 2008), and during the period 2008-2010 the Atlantic Water surface temperatures were above the long term mean (NOAA 2010). This positive anomaly in the sea temperature in Northeast Atlantic continued in 2011-2013 (IESNS report 2013). The increase in SST at several of the stations in the NE Atlantic has been up to 3°C since the early 1980s. This rate of warming is very high relative to the rate of global warming (ICES 2007, 2008). The upper layers of the North Atlantic and Nordic Seas remained exceptionally warm and saline in 2006 and 2007 compared with the long-term average (ICES WGOH 2007, 2008), but also above the long-term average in 2008-2013. The largest anomalies were observed at high latitudes. The North Sea, Baltic Sea and Bay of Biscay had an unusually warm winter and spring. This was due to a combination of stored heat from the warm autumn in 2006, and high solar radiation in 2007 (ICES WGOH 2008). A similar trend was evident in 2008-2010, but not as extreme as the two years before. In 2011 this trend seems to have been further weakened.

Phytoplankton

Phytoplankton abundance in the NE Atlantic has increased in cooler regions (north of 55°N) and decreased in warmer regions (south of 50°N) (Tasker *et al.* 2008). These changes in the primary production are likely to have impacts on zooplankton because of tight trophic coupling (Richardson and Schoeman, 2004). In the Norwegian Sea the average phytoplankton concentrations have shown a reducing trend the last decade, whereas the North Sea has shown an increased trend in phytoplankton concentrations the last few years (Naustvoll *et al* 2010).

Zooplankton

Indicators of zooplankton communities which have been developed over recent years reveal important changes in the pelagic ecosystems of the North East Atlantic (Beaugrand, 2005). A northwards shift of 10° of latitude of the biogeographical boundaries of copepod species has, for instance, occurred during the past four decades (Beaugrand *et al*. 2002). One well-known example of these changes is the decline in the North Sea of the sub-arctic copepod *Calanus finmarchicus*, an important food item for a number of fish species, and its replacement by *Calanus helgolandicus*, a temperate water species. This invasive species dominates at times along the southwestern coast of Norway (Ellertsen and Melle 2009). Due to a different life-strategy and the lack of suitability as food, any increase in the population of this species at the expense of *C. finmarchicus* might have a detrimental effect on pelagic planktivorous fish e.g. mackerel, herring and blue whiting. Progressive increases in abundance of warm water/sub-tropical phytoplankton species into more temperate areas of the northeast Atlantic (Beaugrand *et al*. 2005) have in turn influenced zooplankton communities. The average biomass of zooplankton in the Norwegian Sea has followed a decreasing trend since 2002, and reached a record low in 2009, but have shown an upward trend since then (IESNS report 2013). The overall distribution pattern of zooplankton biomass has changed during the recent years. Previously the highest biomass of zooplankton was usually observed in the cold waters of the East Icelandic Current, where high aggregations of adult herring and mackerel were also observed. From about 2009 these western high density areas are less pronounced (IESNS report, 2012).

The reason for a decline in the biomass index of zooplankton during the period 2002-2009 in Nordic Seas is unknown. A number of possible reasons could explain this decline and the present low level, including reduction in phytoplankton (Naustvoll *et al* 2010; i.e. bottom-up), possible changes in phytoplankton community, possible changes in zooplankton community, and increased grazing pressure by pelagic fish stocks (i.e. bottom-down). Simultaneously to the recent (2009-2013) upward trend in the zooplankton index in May (IESNS report 2013), as well as in the IESSNS surveys in July/August (2011-2013; Nøttestad et al. 2013), the weight-at-age (this report) and length-at-age (WGINOR report 2013) in the Norwegian spring-spawning herring feeding in the area are showing increasing trend. It is an indication that the Norwegian Sea is neither being overgrazed at present by the pelagic fish stocks in the area, nor that the herring stock is starving (i.e. increased natural mortality) because of relatively low zooplankton indices in recent years, as was hinted at in last year's WGWIDE report (ICES 2013a). Further studies on this issue will take place within the ICES working group on integrated assessment in Norwegian Sea (WGINOR report 2013), where the zooplankton index will also be revised and produced for the different areas in the Nordic Seas. The goal of WGINOR is to come up with a holistic ecosystem assessment of the Norwegian Sea and it will be the task in the years to come.

Species interactions

A central element in ecosystem considerations is how different species interact with each other (Rothschild 1986, Skjoldal *et al*. 2004). The distribution of species considered by WGWIDE can overlap to a large extent during some part of the year and according to life history stages. Since these species are mainly planktivorous, density dependent competition for food could be expected. All the species are potential predators on eggs and larvae and the larger species (mackerel and horse mackerel) are also potential predators of the juveniles. Consequently, cannibalism and inter-specific interaction between pelagic species could play an important role in the dynamics of these pelagic stocks.

Various pelagic species (e.g. mackerel, horse mackerel, sardine, blue whiting) also represent an important food source for many top predators such as marine mammals, seabirds and other species of pelagic fish. Many pelagic ecosystems (particularly those in upwelling areas) are characterised by a wasp-waist control, where a few, but highly abundant fish species effectively regulate the populations of their prey (top-down control) but also of their predators (bottom-up control). This type of regulatory mechanism makes pelagic fish have a key role in ecosystem functioning (Skjoldal *et al*. 2004).

There is a large body of literature on the diet of predator species feeding on pelagic fish in the Northeast Atlantic: sardine, mackerel, horse mackerel, blue whiting and herring have all been found in the diet of several cetacean and seabird species and are also part of the diet of other fish species (e.g. hake, tuna found with sardine and anchovy) (Anker Nilssen and Lorentzen, 2004; Nøttestad and Olsen 2004). Comparison of population estimates of pelagic fish (TSB and SSB herring: 14.4 and 11.5 mill. tons, mackerel: 3.6 and 2.5 mill. tons and blue whiting: 5.761 and 4.918 mill. tons) (WGWIDE 2009)) with those of top predators (e.g. minke whale, fin whale, killer whales) it would appear that predation on pelagic fish by other pelagic fish has a much bigger potential for impact in regulating populations than that the predation by marine mammals and seabirds (Furness (2002), in the context of the North Sea). Nevertheless, top predators could play a bigger role in pelagic fish dynamics at regional or local scales particularly when fish biomass is low (Holst *et al*. 2004; Nøttestad *et al*. 2004).

2 Northeast Atlantic Mackerel

2.1 ICES Advice and International Management Applicable to 2013

From 2001 to 2007 the internationally agreed TACs covered most of the distribution area of the northeast Atlantic mackerel. Since 2008, no agreement has been reached among the Coastal States on the sharing of the mackerel quotas. An overview of the declared quotas and transfers for 2013, as available to WGWIDE, is given in the text table below. Total removals of mackerel are expected to be approximately 896 kt in 2013, exceeding the recommended TAC for 2013 of between 497 and 542 kt.

2013 quota component	Expected **catch** amount (t)
EU (incl. Swedish quota)	338 392
- Spanish payback	-8 126
- Other EU payback	-6
Norway	153 597
Russia	68 359
Iceland	123 182
- Iceland transfer from 2012 -> 2013	2 827
Faroes	125 852
- Faroes transfer from 2012 -> 2013	32 000
Greenland	50 044
Discards	15 380
Expected overcatch	-6 165
Total	895 336

The quota figures and transfers in the text table above were based on various national regulations and official press releases, and the discards and expected overcatch were WGWIDE estimates.

Various international and national measures to protect mackerel are in operation throughout the mackerel catching countries. Refer to Table 2.2.4 for an overview.

2.2 The Fishery

2.2.1 Fleet Composition in 2012

A description of the fleets operated by the major mackerel catching nations is given in Table 2.2.1.

The total fleet can be considered to consist of the following components:

Freezer trawlers. These are commonly large vessels (up to 150 m) that usually operate a single mid-water pelagic trawl, although smaller vessels may also work as pair trawlers. These vessels are at sea for several weeks and sort and process the catch on board, storing the mackerel in frozen 20 kg blocks. The Dutch, German and the majority of the French and English fleets consist of these vessels which are owned and operated by a small number of Dutch companies. They fish in the North Sea, west of the UK and Ireland and also in the English Channel and further south along the western coast of France. The Russian summer fishery in subarea IIa is also prosecuted by freezer trawlers and partly the Icelandic fishery in Va and XIVb.

Purse Seiners. The majority of the Norwegian catch is taken by these vessels, targeting mackerel overwintering close to the Norwegian coastline. The largest vessels (>20m) are RSWs, storing the catch in tanks containing refrigerated seawater. Smaller purse seiners use ice to chill their catch which they take on prior to departure. A purse seine fleet is also the most important component of the Spanish fleet. They are numerous and target mackerel early in the year close to the northern Spanish coast. These are dryhold vessels, chilling the catch with ice. Denmark also has a purse seine fleet operating in the northern North Sea.

Pelagic Trawlers. These vessels vary in size from 20-100 m and operate both individually and as pairs. The largest of the pelagic trawlers use RSW tanks for storage. Iceland, Faroes, Scotland and Ireland all fish mackerel using pelagic trawlers. Scottish and Icelandic vessels mostly operate singly whereas Ireland and Faroes vessels tend to use pair trawls. Spain also has a significant trawler fleet which target mackerel with a demersal trawl in areas VIII and IXaN.

Lines and Jigging. Norway, England have handline fleets operating inshore in the Skagerrak (Norway) and in area VIIe/f (England) around the coast of Cornwall, where other fishing methods are not permitted. Spain also has a large artisanal handline fleet as do France and Portugal. A small proportion of the total catch reported by Scotland (IVa and IVb) and Iceland (Va) is taken by a handline fleet.

Gillnets. Gillnet fleets are operated by Norway and Spain.

2.2.2 Fleet Behaviour in 2012

The most important changes in recent years are related to the geographical expansion of the northern summer fishery (areas II,V and XIVb) and changes in southern waters due to stricter TAC compliance by Spanish authorities. Fishing in the North Sea and west of the British Isles followed a traditional pattern, targeting mackerel on their spawning migration from the Norwegian deep in the northern North Sea, westwards around the north coast of Scotland and down the west coast of Scotland and Ireland.

Fishing by Faroese vessels has increased dramatically in recent years and has shifted exclusively to pair trawling. A small proportion of the Faroese quota is granted to smaller, traditionally demersal trawlers (using pair trawls).

The Russian freezer trawler fleet operates over a wide area in Northern waters. This fleet targets herring and blue whiting in addition to mackerel. In the third quarter the Russian vessels operated over a wider area than previously, including around Jan-Mayen in addition to the more traditional grounds in Faroese and international waters. The Icelandic fishery also expanded with significant catches taken from the south and west of Iceland in 2012. Also targeting mackerel in area XIVb were Greenlandic vessels.

Due to a recent agreement between Norway and EU permitting reciprocal access, Norwegian vessels have been able to take their full quota since 2010, in contrast to 2009 when they were curtailed due to an earlier than expected migration.

In 2010 Spanish authorities introduced a new TAC allocation and control regime which resulted in closure of the mackerel fishery in quarter 2 to the purse seine and artisanal fleets when the majority of their respective quotas were exhausted. Due primarily to changes in the timing of the migration, the fishery was closed in late March in 2012 to purse seiners and artisanal fishers. The trawl fleet fishery was closed by the end of April. Since the turn of the century the Spanish fishery has shifted forward by approximately 30 days. The fishing season starts in the inner part of Bay of Biscay were the bulk of the stock is concentrated; then as the fish is moving westwards, the different fleets follow this migration as shown in Figure 2.2.2.1

2.2.3 Recent Changes in Fishing Technology and Fishing Patterns

Northeast Atlantic mackerel, as a widely distributed species, is targeted by a number of different fishing métiers. Most of the fishing patterns of these métiers remained unchanged during the most recent years, although the timing of the spawning migration and geographical distribution can change from year to year and this affects the fishery in various areas.

Recent changes are notable for two areas and métiers in particular:

In 2010 the Faroese fleet switched from purse-seining in Norwegian and EU waters to pair trawling in the Faroese area. The Faroese fleet used to catch their mackerel quota in Divisions IVa and VIa during September-October with purse-seiners. However, as no agreement was obtained among the Coastal States since 2009, the mackerel quota has been taken in Faroese waters during June-October by the same fleet using pair trawls. The mackerel distribution is more scattered during summer and pair trawls seem to be effective in such circumstances.

Also targeting summer feeding mackerel, Icelandic vessels have increased effort and catch dramatically in recent years from 4kt in 2006 to almost 159kt in 2011. A lower TAC in 2012 resulted in a reduced catch of 149kt. This fishery operates over a wide area E, NE, SE, S and SW off Iceland. Since 2011 there has been less fishing activity to the north and north-east and an increase in catches taken south and west of Iceland. In addition, Greenland has reported increased catches from area XIVb since 2011.

Part of the northeast Atlantic mackerel population migrates towards the southern spawning area (ICES Division VIIIc - Cantabrian Sea) at the end of winter. Catch, survey and biological data indicate a forward shift in timing of spawning migration of the southern component of mackerel in the last decade (Punzón and Villamor 2009; Villamor *et al* WD 2011). This temporal shift of about one month in the migration pattern of mackerel to the southern area might be linked to the fact that average temperatures in this area have been trending higher during winter-spring in the last few years.

2.2.4 Regulations and Their Effects

An overview of the major existing technical measures, TACs, effort controls and management plans are given in Table 2.2.4. Note that there may be additional existing international and national regulations that are not listed here.

Since 2010 no Coastal State Agreement/NEAFC Agreement has been reached so no overall international regulation on catch limitation is in force.

Management aimed at a fishing mortality in the range of 0.15–0.20 in the period 1998 - 2008. The current management plan aims at a fishing mortality in the range 0.20-0.22. The fishing mortality realised during 1998-2008 was in the range of 0.22 to 0.45.

Implementation of the management plan resulted in reduced fishing mortality and increased biomass. Since 2008 catches have greatly exceeded those given by the plan.

The measures advised by ICES to protect the North Sea spawning component aim at setting the conditions for making a recovery of this component possible. Before the late 1960s, the North Sea spawning biomass of mackerel was estimated at above 3 million tonnes. Due to overexploitation, recruitment has failed since 1969, leading to a decline in the size of this component. The North Sea spawning component has increased since 1999, but continued protection is needed as it is still considered to be very small.

The closure of the mackerel fishery in Divisions IVb,c and IIIa throughout the whole year is designed to protect the North Sea component in this area and also the juvenile western mackerel which are numerous, particularly in Division IVb,c during the second half of the year. This closure has unfortunately resulted in increased discards of mackerel in the non-directed fisheries (especially horse mackerel fisheries) in these areas as vessels at present are permitted to take only 10% of their catch as mackerel bycatch. No data on the actual amount of mackerel taken as bycatch are available, but the reported landings of mackerel in Divisions IIIa and IVb,c from 1997 onwards might seriously underestimate catches due to discarded bycatch.

The advised closure of Division IVa for fishing during the first half of the year is based on the perception that the western mackerel enter the North Sea in July/August, and stay there until December before migrating to their spawning areas. Updated observations taken in the late 1990s suggested that this return migration actually started in mid- to late February. This was believed to result in large-scale misreporting from the northern part of the North Sea (Division IVa) to Division VIa. Recent EU TAC regulations have permitted some small quotas in IIIa and IVb,c. In the same regulation it is also stated that within the limits of the quota for the western component (VI, VII, VIIIa,b,d,e, Vb (EU), IIa (non EU), XII, XIV), a certain quantity of this stock may be caught in IVa but only during the periods 1 January to 15 February and 1 September to 31 December.

In the southern area a Spanish national regulation affecting mackerel catches of Spanish fisheries has been implemented since 2010 distributing the Spanish catch quota by gear (30.5% quota for trawlers, 27.7% for purse seiners and 34.6% for artisanal fisheries), half-year and area. Additionally, a stricter control on mackerel landings by Spanish fishery administration was enforced. In 2011 the EU introduced a new regulation scheduling payback until 2015 due to overfishing of the mackerel quota allocated to Spain in 2010 (Commission Regulation (EU) No 165/2011). A similar regulation applied to Scottish and Irish vessels expired in 2012.

Within the area of the southwest Mackerel Box off Cornwall in southern England only handliners are permitted to target mackerel. This area was set up at a time of high fishing effort in the area in 1981 by Council Regulation to protect juvenile mackerel, as the area is a well known nursery. The area of the box was extended to its present size in 1989.

Additionally, there are various other national measures in operation in some of the mackerel catching countries.

2.3 Catch Data

2.3.1 WG Catch Estimates

The total estimated Working Group catch for 2012 was 892,762t, a decrease of 46,057t on the estimated catch in 2011. Catches increased substantially from 2006-2010 and have averaged 900kt since 2011.

The combined 2012 TACs arising from agreements and autonomous quotas amount to 878,578t. The Working Group catch estimate represents an undershoot of approximately 1%. The combined fishable TAC for 2013, as best ascertained by the Working Group (see section 2.1), amounts to 868,461t. Of this TAC Spain has agreed not to fish 8,126t.

Catches reported for 2012 and in previous Working Group reports are considered to be best estimates. In most cases, catch information comes from official logbook records. Other sources of information include catch processors. Some countries provide information on discards and slipped catch from observer programs, logbooks and compliance reports. In several countries discarding is illegal. Spanish data is based on the official data supplied by the Fisheries General Secretary (SGP) but supplemented by scientific estimates which are recorded as unallocated catch in the WG estimates (see section 1.3.7)

The text table below gives a brief overview of the basis for the working group catch estimates.

Country	Official Log Book	Other Sources	Discard Information
Denmark	Y (landings)	Y (sale slips)	Y
Faroe	Y (catches)	Y (coast guard)	NA[1]
France	Y (landings)		N
Germany	Y (landings)		Y
Iceland	Y (landings)		N
Ireland	Y (landings)		Y
Netherlands	Y (landings)	Y	Y
Norway	Y (catches)		NA[1]
Portugal		Y (sale slips)	Y
Russia	Y (catches)		NA[1]
Spain	Y	Y	Y
Sweden	Y (landings)		N
UK	Y (landings)	Y	N

[1]In the Russian, Norwegian and Faroese fleets discarding is illegal, which means officially landings are equal to catches.

The Working Group considers that the estimates of catch are likely to be an underestimate for the following reasons:

Estimates of discarding or slipping are either not available or incomplete for most countries. Anecdotal evidence suggests that discarding and slipping can occur for a number of reasons including high-grading (fish weighing more than 600g attracts a premium price), lack of quota, storage or processing capacity and when mackerel is taken as by-catch

Confidential information suggests substantial under-reported landings for which numerical information is not available for most countries. Recent work has indicated considerable uncertainty in true catch figures (Simmonds et al 2010) for the period studied.

Estimates of the magnitude and precision of unaccounted mortality suggests that, on average for the period prior to 2007, total catch related removals were equivalent to 1.7 to 3.6 times the reported catch (Simmonds et al. 2010)

Reliance on logbook data from EU countries implies (even with 100% compliance) a precision of recorded landings of 89% from 2004 and 82% previous to this (Council Regulation (EC) Nos. 2807/83 & 2287/2003). Given that over reporting of mackerel landings is unlikely for economic reasons, the WG considers that, where based on logbook figures, the reported landings may be an underestimate of up to 18% (11% from 2004). Where inspections were not carried out there is a possibility of a 56% under reporting, without there being an obvious illegal record in the logsheets. Without information on the percentage of the landings inspected it is not possible for the Working Group to evaluate the underestimate in its figures due to this technicality. EU landings represent about 65% of the total estimated NEA mackerel catch

The accuracy of logbooks from countries outside the EU has not been evaluated by WGWIDE. Monitoring of logbook records is the responsibility of the national control and enforcement agencies.

The total catch as estimated by the Working Group is shown in Table 2.3.1.1. It is broken down by ICES area and illustrates the development of the fishery since 1969.

Discard Estimates

With a few exceptions, estimates of discards have been provided to the Working Group for the areas VI, VII/VIIIa,b,d,e and III/IV (see Table 2.3.1.1) since 1978. However, the Working Group considers the estimates for these areas as incomplete. In 2012 discard data for mackerel were provided by six nations: The Netherlands, Germany, Ireland, Spain, Portugal and Denmark. Total discards amounted to 15,380t from these nations (mainly Netherlands and Spain). The German program consisted of 2 mackerel-directed trips on pelagic freezer trawlers. The Danish discards apply only to observations from some demersal fisheries. The Irish pelagic discard program included 36 trips (for all pelagic species).

Age-disaggregated data was made available to the Working Group from Portugal and Spain indicating that the vast majority of discarded fish were age 0 or 1 in areas VIII and IX. In area VII, particularly in the first quarter, in which the greatest discarding was recorded, the discarded catch consisted of a wider range of ages although 98% of the discarded catch was age 6 or younger.

Discarding of small mackerel has historically been a major problem in the mackerel fishery and was largely responsible for the introduction of the south-west mackerel box. In the years prior to 1994 there was evidence of large-scale discarding and slipping of small mackerel in the fisheries in Division IIa and Sub-area IV, mainly because of the very high prices paid for larger mackerel (>600g) for the Japanese market. This factor was put forward as a possible reason for the very low abundance of the 1991 year class in the 1993 catches. Anecdotal evidence from the fleet suggests that since 1994, discarding/slipping has been reduced in these areas.

In some of the horse mackerel directed fisheries e.g. those in Subareas VI and VII mackerel is taken as by-catch. Reports from these fisheries have suggested that discarding may be significant because of the low mackerel quota relative to the high horse mackerel quota - particularly in those fisheries carried out by freezer trawlers in the fourth quarter. The level of discards is greatly influenced by the market price and by quotas.

2.3.2 Distribution of Catches

The fishery has changed significantly in the recent past. Of the total catch in 2012, Norway accounted for the greatest proportion (20%) followed by Iceland (16%), Scotland (15%) and Faroe (12%). In the absence of an international agreement, Faroe and Iceland set their own quotas in 2012. Russia (8%) and Ireland (7%) also have large fisheries with Danish, Dutch, French and Spanish catches in 2012 of greater than 20kt. Spanish catches have reduced significantly in recent years, primarily due to stricter enforcement.

In 2012, catches in the northern areas (II, V, XIV) amounted to 447,207 t, an increase of 49,075t on the 2011 catch and more than 283,000 t greater than the catch in 2009 (see Table 2.3.2.1). Icelandic and Faroese catches decreased although Norwegian catches increased by 65kt as a greater proportion of the Norwegian quota was taken in area IIa than in 2011. The wide geographical distribution of the fishery noted in previous years has continued with substantial catches taken in area XIVb (6kt Iceland, 5kt Greenland).

The time series of catches by country from the North Sea, Skagerrak and Kattegat (Subarea IV, Division IIIa) is given in Table 2.3.2.2. Catches in 2012 amounted to 218,940 t, a decrease on 2011 corresponding to the large Norwegian catches as outlined above. Small catches were also reported in areas IIIb,c and d.

Catches in the western area (Subareas VI,VII and Divisions VIIIa,b,d and e) were 197,826 t and remain close to the long term average. These catches are detailed in Table 2.3.2.3.

Table 2.3.2.4 details the catches in the southern areas (Division VIIIc and Subarea IXa) which are taken almost exclusively by Spain and Portugal. The reported catch of 28,789t is approximately 10kt above that in 2011 but is still relatively low when compared to earlier recent years (52,194t and 107,748t in 2010 and 2009 respectively). The reduced catch is primarily a result of stricter TAC compliance by Spanish administrators. A new regulation in 2010 allocated quota between the fleets (trawl, purse seine and artisanal). During the 2nd quarter the majority of the quota was exhausted and the fishery closed.

The distribution of catches by quarter (%) is described in the text table below:

Year	Q1	Q2	Q3	Q4
1990	28	6	26	40
1991	38	5	25	32
1992	34	5	24	37
1993	29	7	25	39
1994	32	6	28	34
1995	37	8	27	28
1996	37	8	32	23
1997	34	11	33	22
1998	38	12	24	27
1999	36	9	28	27
2000	41	4	21	33
2001	40	6	23	30

Year	Q1	Q2	Q3	Q4
2002	37	5	29	28
2003	36	5	22	37
2004	37	6	28	29
2005	46	6	25	23
2006	41	5	18	36
2007	34	5	21	40
2008	34	4	35	27
2009	38	11	31	20
2010	26	5	54	15
2011	22	7	54	17
2012	22	6	48	24

The quarterly distribution of catch in 2012 is similar to 2010-2011 with the Northern summer fishery in Q3 accounting for the greatest proportion of the total catch. Fisheries in area IIa extended into quarter 4 to a greater extent than in previous years.

Catches per ICES statistical rectangle are shown in Figures 2.3.2.1 to 2.3.2.4. It should be noted that these figures are a combination of official and WG catches and may not indicate the true location of the catches or represent the location of the entire stock. These data are based on catches reported by all the major catching nations and represents almost the entire WG catch.

- First quarter 2012 (194 567t – 22%)

  The distribution of catches in the first quarter is shown in Figure 2.3.2.1. The quarter 1 fishery is similar to that in previous years with the Scottish and Irish pelagic fleets targeting mackerel in VIa, VIIb and VIIj. Substantial catches are also taken by the Dutch owned freezer trawler fleet. The largest catches were taken in area VIa, as was the case in 2011. The Spanish fisheries also take significant catches along the north coast of Spain during the first quarter.

- Second quarter 2012 (52 736 – 6%)

  The distribution of catches in the second quarter is shown in Figure 2.3.2.2. The quarter 2 fishery is traditionally the smallest and this was also the case in 2012. The most significant catches occurred towards the end of the quarter in the northern areas by Icelandic and Russian fleets. Large catches southeast of Iceland and north of Faroe were reported.

- Third quarter 2012 (431 814 – 48%)

  Figure 2.3.2.3 shows the distribution of the quarter 3 catches. Large catches were taken throughout areas IIa (Russian, Norwegian vessels), IVa (Norwegian, Scottish vessels), Vb (Faroese vessels) and Va (Icelandic vessels). The fishery extended slightly further west than in 2011 with increased catches reported in area XIVb by both Iceland and Greenland. The highest catches remain those from SE Iceland, north of the Faroes and around the Shetland Isles.

- Fourth quarter 2012 (213 645t – 24%)

The fourth quarter distribution of catches is shown in Figure 2.3.2.4. The summer fishery in northern waters has largely finished, with the bulk of the catch taken by Norway, Scotland and Ireland around the Shetland Isles and along the north coast of Scotland. The pattern of catches is very similar to that reported in recent years with the exception of the catches in IIa, north of Faroe.

2.3.3 Catch-at-Age

The 2012 catches in number-at-age by quarter and ICES area are given in Table 2.3.3.1. This catch in numbers relates to a total Working Group catch of 892,762t. These figures have been appended to the catch-at-age assessment table (see Table 2.6.1.1).

Age distributions of commercial catch were provided by Denmark, England, Germany, Faroes, Iceland, Ireland, the Netherlands, Norway, Portugal, Russia, Scotland and Spain. There remain gaps in the age sampling of catches, notably for French, Swedish and Northern Irish fleets.

Catches for which there were no sampling data were converted into numbers-at-age using data from the most appropriate fleets. Accurate national fleet descriptions are required for the allocation of sample data to unsampled catches. The sampling coverage is further discussed in Section 1.3.

The percentage catch numbers-at-age by quarter and area are given in Table 2.3.3.2.

Almost 70% of the catch in numbers consists of 4-7 year olds. As in 2011, the 2006 year classes is the most populous in the catch at 21% of catch by number respectively, particularly in the heavily exploited northern areas (IIa,Va and VIa). In subareas VIIa,d,e,f,g and h, young mackerel (1-3 year olds) account for over half the catch by number although these areas are relatively lightly exploited. In subareas VIIIc and IXa the catch is also dominated by juvenile fish.

2.3.4 Effort and Catch per Unit Effort

The effort and catch-per-unit-effort from the commercial fleets is only provided for some fleets in the southern area.

Table 2.3.4.1 and Figure 2.3.4.1 show the fishing effort data from Spanish commercial fleets. The table includes effort from Santoña and Santander handline fleets (Subdivision VIIIc East) for which mackerel is the target species from February to May, and annual effort from A Coruna trawl fleet (Subdivision VIIIc West). Spanish fleet effort figure shows a significant decrease in 2003 due to the catastrophe of the Prestige oil spill. Hand-line fleet effort showed an increasing trend from 1993 to 1998 but since then the effort, excluding the ban due to the Prestige, shows a clear declining trend, more relevant for the Santoña fleet, which could be related with the shift of the mackerel availability period from February-May to January-February. The effort of the Spanish trawler fleet is quite stable.

Figure 2.3.4.2 and Table 2.3.4.2 show the CPUE corresponding to the Spanish fleets referred above. There is clear drop in the handline fleets CPUE since 2011 which could be related with the daily quota established for 2011. On the contrary the trawler fleet from A Coruña shows an increasing trend in its CPUE since 2007.

2.4 Biological Data

2.4.1 Length Composition of Catch

The mean lengths-at-age in the catch per quarter and area for 2012 are given in Table 2.4.1.1.

For the most common ages which are well sampled there is little difference to recent years. The length of juveniles is traditionally rather variable. 0-group and age 3 fish are 2cm shorter than in 2011 with age 1 of a similar length. Given the rapid growth of 0-group fish, the variability due to sampling of these fish which do not appear in the catches until quarter 3 is likely to be the most significant factor. In recent years, more juvenile fish have been sampled in northern waters. Previously, these fish were only caught in the southern fishery. Older fish 8+ have reduced in length by approximately 0.5cm. This is consistent with an observed reduction in catch weight.

Length distributions of the 2012 catches were provided by England, Faeroes, Iceland, Ireland, Germany, the Netherlands, Norway, Portugal, Russia, Scotland and Spain. The length distributions were available from most of the fishing fleets and account for over 90% of the catches. These distributions are only intended to give an indication of the size of mackerel caught by the various fleets and are used as an aid in allocating sample information to unsampled catches. Selected length distributions by country and fleet for 2012 catches are given in Table 2.4.1.2. They show clear differences between quarters, particularly for the Spanish, Portuguese and English fleets.

2.4.2 Weights-at-Age in the Catch and Stock

The mean weights-at-age in the catch per quarter and area for 2012 are given in Table 2.4.2.1. Deviations from the weights recorded in 2011 are of a similar magnitude to previous years although there appears to be a trend emerging towards lighter weights-at-age for the older age classes. Any changes in weight-at-age are consistent with the changes noted in length in Section 2.4.1.

The Working Group used weights-at-age in the stock calculated as the average of the weights-at-age in the three spawning components, weighted by the relative size of each component, as estimated by the 2013 egg survey for the southern and western components and the 2011 egg survey for the North Sea component. Mean weights-at-age for the western component are estimated from Dutch commercial catch data collected in Division VIIj,h and VIIIa over the period March to May 2011, areas and period which correspond to the spawning distribution of mackerel. Over the recent period, the fishing fleet reduced is activity in this area in that time of the year and the number of fish sampled from the commercial catches has been decreasing. This year, only one sample of 25 fish for the Dutch fleet was available. The commercial catches samples were combined with weights derived from data collected on the 2013 egg survey (666 fish), as stipulated in the stock annex. For the North Sea spawning component, mean weights-at-age were calculated from samples of the commercial catches collected from areas IVa and IVb in the second quarter. Stock weights for the southern component are based on samples from the Portuguese and Spanish catch taken in VIIIc and IXa in the 2nd quarter of the year, combined with weights derived from data collected on the 2013 mackerel egg survey. The weight for age 1 fish since 2008 is the average of the weights-at-age 1 in 2005-2007 due to lack of sample data since 2008, in the western component which dominates the stock.

The 2012 stock weights-at-age are substantially lower than the 2011 weights-at-age (Figure 2.4.2.1). However, except for the year 2011, the general trend among most ages is a decrease in weights-at-age, also observed in the catch weights-at-age. Given this decreasing trend, using 2013 data (egg survey data) to compute the 2012 stock weights-at-age may have accentuated this decrease.

Data source	North Sea	Western Component		Southern Component		NEA Mackerel
Age	Catch	Catch	Survey	Catch	Survey	Weighted mean
0						0.000
1				0.100	0.103	0.071[1]
2	0.174		0.142	0.163	0.131	0.143
3	0.260		0.169	0.214	0.161	0.179
4	0.307	0.311	0.243	0.247	0.271	0.248
5	0.357	0.370	0.281	0.282	0.303	0.288
6	0.378	0.372	0.308	0.327	0.328	0.317
7	0.428	0.472	0.339	0.361	0.343	0.351
8	0.486	0.496	0.359	0.414	0.360	0.372
9	0.454	0.517	0.383	0.438	0.416	0.405
10	0.425		0.424	0.461	0.488	0.436
11	0.510	0.739	0.462	0.467	0.544	0.491
12+	0.532	0.623	0.524	0.492		0.533
Component Weighting	2.86%		74.05%		23.09%	

[1]average of the 2005-2007 estimates of weight at age 1

2.4.3 Natural Mortality and Maturity Ogive

Natural mortality is assumed to be 0.15 for all age groups and constant over time.

The maturity ogive for 2012 was calculated as the average of the ogives of the three spawning components (which are fixed over time) weighted by the relative size of each component calculated as described above for the stock weights.

Age	North Sea	Western Component	Southern Component	NEA Mackerel
0	0	0	0	0.00
1	0	0.08	0.02	0.06
2	0.37	0.60	0.54	0.58
3	1	0.90	0.70	0.86
4	1	0.97	1	0.98
5	1	0.97	1	0.98
6	1	0.99	1	0.99
7	1	1	1	1.00
8	1	1	1	1.00
9	1	1	1	1.00
10	1	1	1	1.00
11	1	1	1	1.00
12+	1	1	1	1.00
Component Weighting	2.86%	74.05%	23.09%	

2.5 Survey Data

2.5.1 International Mackerel and Horse Mackerel Egg Surveys

The ICES Triennial Mackerel and Horse Mackerel Egg Survey was carried out during January - July 2013. Final results will be presented at the WGMEGS meeting in April 2014. Since 2004 and subsequent to demands for up-to-date data for the assessment, WGMEGS aims to provide a preliminary estimate of NEA mackerel biomass and western horse mackerel egg production in time for the assessment meetings within the same calendar year as the survey.

This requires a complete work-up of the data from the egg survey itself as well as the histological data on mackerel fecundity and atresia. The production of useable estimates for both species requires considerable commitment from the members of WGMEGS. WGWIDE were both aware and appreciative of this. A survey report with the preliminary results of the survey was presented to WGWIDE members on time (see Burns et al. 2013, WD for further details).

In keeping with the last surveys in 2007 and 2010, the survey was split into six sampling periods. The deployment of vessels to areas and periods is summarized in Table 2.5.1. Overall the vessel deployment and effort in 2013 was very similar to that of 2010. Analyses of the plankton and fecundity samples were carried out according to the sampling protocols as described in the WGMEGS Survey Manual v1.2 (WGMEGS 2013, Annex 2).

2.5.1.1 Data analysis for mackerel annual egg production

Egg counts were converted to stage 1 egg production, using data on the volume of water filtered and on the depth sampled. These values were then converted to egg production/day/m^2 using the development equations and water temperature at 20m depth. Arithmetic means were used where more than one sample per rectangle per period was collected. Daily egg production values were interpolated into unsampled rectangles according to procedures described in the above report. Plots of the distribution of egg production for the western area are presented in Figures 2.5.1.1-2.5.1.6. Interpolated values are highlighted in red. The area coverage is described in detail in Burns *et al*. 2013.

Figure 2.5.1.7 presents the egg production curve for the western area for the 2013 survey, along with those for the previous surveys for comparison. 2010 provided an unusually large spawning event early in the spawning season; however, in 2013 an even larger spawning event was observed that provides evidence that spawning is almost certainly taking place well in advance of the nominal start date of 10th February (day 42). The nominal end-of-spawning date of the 31st July is also the same as that used in previous years and the shape of the production curve during this period does not suggest that the existing end date should be altered. The standard error has not yet been calculated, but because of the increase in survey area and a greater subsequent number of interpolated samples the expectation is that it will be larger compared to 2010. The provisional total annual egg production (TAEP) for the western area in 2013 was calculated as 2.31×10^{15}. This is a 27% increase on the 2010 TAEP which was 1.69×10^{15}. The spawning curve is very similar to that observed in 2010 which displayed the largest spawning event in the first sampling period of the western area. Period 2 and pre-period 2 egg production accounted for 70% of the overall egg production in the western area in 2013.

Figure 2.5.1.8 shows the egg production curve for the southern area for the 2013 survey, along with those for previous surveys for comparison. The start date for spawning in the southern area was the 30th January and is the same as was used in 2010 and is based on the occurrence of stage I eggs found off the Portuguese coast during the period 1 survey. The same end-of-spawning date of the 17th July was used again this year. The provisional total annual egg production (TAEP) for the southern area in 2013 was calculated as 6.77×10^{14}. This is a 59% increase on the 2010 TAEP which was 4.26×10^{14}. In contrast to both the 2007 and 2010 results peak spawning has moved back from period 2 to period 3 (28th March – 6th May).

A comparison of the total annual egg production for the western and southern area over the last survey years is given below:

Year	Western TAEP	Southern TAEP
2013	$2.31 * 10^{15}$	$6.77 * 10^{14}$
2010	$1.54 * 10^{15}$	$4.33 * 10^{14}$
2007	$1.22 * 10^{15}$	$3.12 * 10^{14}$
2004	$1.20 * 10^{15}$	$1.26 * 10^{14}$
2001	$1.21 * 10^{15}$	$2.83 * 10^{14}$
1998	$1.37 * 10^{15}$	$4.34 * 10^{14}$

2.5.1.2 Mackerel fecundity and atresia estimation

Estimates of fecundity are given as realised fecundity which is the potential fecundity minus the atresia rate (for details see Burns et al. 2013). The analysis of potential fecundity is carried out by six different participating institutes. Preliminary results based on a limited number (88) of samples from period 2 and 3 showed a potential fecundity of 1248 oocytes/gram female. Due to time constraints no samples were analysed for atresia at the time of WGWIDE. For the preliminary estimation of the realised fecundity the mean atresia rate based on the last four survey years (7 %) was used. This resulted in a preliminary realised fecundity estimate for 2013 of 1161 oocytes/gram female fish.

2.5.1.3 Quality and reliability of the 2013 egg survey

In 2013 the peak of spawning was not only significantly larger but it was also earlier than in 2010. Subsequent to the 2010 survey and observed early peak of spawning, sampling for the 2013 survey was brought forward by almost 3 weeks in the western area. The results, however, suggest this may be insufficient and a very real concern exists that the start of spawning may not have been fully captured during the 2013 survey.

Otherwise, despite severe weather that was encountered during large periods of the 2013 survey programme coupled with significant technical problems experienced on several of the participating vessels, the 2013 triennial egg survey was successful in providing comprehensive coverage of the spawning areas of both mackerel and horse mackerel. Whilst the expansion of the mackerel western spawning area in periods 3 - 5 continues to be a concern, the egg production in these areas compared to the main areas of peak spawning in period 2 remains very low.

Further analysis of the quality and reliability of the survey will be done by WGMEGS in April 2014.

2.5.1.4 Mackerel biomass estimates

Based on the total annual egg production (TAEP) for the western and southern component, a realized fecundity estimate of 1161 oocytes/g female, a sex ratio of 1:1 and a raising factor of 1.08, the preliminary total spawning stock biomass (SSB) was estimated as shown below:

$$SSB = \frac{TAEP}{F'} * s * cf$$

where

F′ = realized fecundity,
s = 2 for a given sex ratio of 1:1,
cf = 1.08 (fixed raising factor to convert pre-spawning to spawning fish)

giving

- 4.3 million tonnes for the western component (2010: 3.431, 2007: 2.945)
- 1.259 million tonnes for the southern component (2010: 0.858, 2007: 0.701)
- 5.56 million tonnes for the western and southern components combined (2010: 4.289, 2007: 3.646).

2.5.2 Combined survey recruitment indices

Analysis carried out in 2008 (ICES CM 2008/ACOM:13) indicated that recruitment series from survey data continued to be ineffective as a means for estimating or predicting recruitment for NEA mackerel. The data series continues to be kept up but these data are not presented here and were not included in the stock assessment or short-term predictions. See Stock Annex for additional information. New analyses are anticipated to be included in the 2014 benchmark.

2.5.3 Acoustic and Pelagic trawl surveys

2.5.3.1 International Ecosystem survey in the Norwegian Sea (IESNS)

Mackerel

In recent years an increasing amount of mackerel has been observed in the Norwegian Sea during the combined survey in May targeting NSS herring and Atlantic blue whiting. The edge of the distribution has also been found progressively further north and west. In May 2013 the mackerel was mainly found in the eastern part of the survey area up to 66°N. In the western part, or west of 0°, it was only observed in two trawl hauls in May 2012 and not in the northwestern part of the survey area as in 2011. This changed distribution relative to last year is probably caused by the relatively cold temperature in the south western part of the area.

2.5.3.2 Ecosystem surveys in the Nordic Seas in July–August (IESSNS)

Northeast Atlantic Mackerel and Ecosystems

In July-August 2013, four vessels: the chartered trawler/purse seiners M/V “Libas”, M/V “Eros” (Norway), M/V “Finnur Fridi” (Faroe Islands), and the research vessel R/V “Arni Friðriksson” (Iceland) participated in the joint ecosystem survey (IESSNS; Nøttestad et al 2013) in the Norwegian Sea and surrounding waters. The five weeks of cruises from 2nd of July to 9th August 2013 are part of a long-term project to collect updated and relevant data on abundance, distribution, aggregation, migration and ecology of northeast Atlantic mackerel and other major pelagic species. Major aims of the survey were to quantify abundance, spatio-temporal distribution, aggregation and feeding ecology of northeast Atlantic mackerel in relation to distribution of other pelagic fish species such as Norwegian spring-spawning herring and blue whiting, oceanographic conditions and prey communities. Whale observers were operating on the Norwegian vessels to collect data on distribution and aggregation of marine mammals.

All vessels that participated in the IESSNS 2013 survey used the same designed pelagic sampling trawl (Multpelt 832) and similar protocol for both rigging and operation agreed upon in Hirtshals in February 2013 from the ICES WKNAMMM workshop between the industry and scientists (ICES CM 2013/SSGESST:18). The swept area methodology for abundance estimation of NEA mackerel was further developed by dedicated experiments with parallel trawling and direct comparison of mackerel trawl catches between vessels in the same areas. Trawling experiments were done with multi-beam sonar monitoring of mackerel behaviour and aggregation before and during trawling. Systematic underwater video recordings of mackerel swimming and aggregation behaviour, patchiness and catchability were also conducted. More dedicated catchability studies will be performed in 2014. More detailed studies on age disaggregated biomass estimates and exploration on how well the different year classes in the NEA mackerel stock can be followed from year to year have already been initiated.

Survey tracks

The four vessels followed predetermined survey lines with pre-selected pelagic trawl stations (Figure 2.5.3.2.1). The cruise tracks covered several Exclusive Economic Zones (EEZs): Norwegian EEZ (including Norway mainland, Jan Mayen EEZ and Svalbard zone), EU EEZ, Faroese EEZ, Icelandic EEZ, Greenlandic EEZ, and International waters. CTD stations from the surface to 500 m depth in combination with WP2 plankton net samples from the surface down to 200 m depth were taken systematically on every pelagic trawl station onboard all vessels.

Temperature

The temperatures in the Nordic Seas in July-August 2013 are now close to the long-term average except for in the northern part of the Norwegian Sea with 1-2°C higher temperatures than the long-term average temperature during the last 20 years (Figure 2.5.3.2.2). The temperature in the upper layers (10m and 20m) shows warm water of Atlantic origin covering most of the survey area (Figure 2.5.3.2.3). Generally the temperature pattern in the survey area in 2013 was similar to the 2012 situation, except for the absence of the warm water mass observed south of Iceland in 2012. This year the coverage was extended southwards, and the highest temperature was recorded in this area, especially in the south-east, where it reached 12-13°C. Most of the Norwegian Sea and the area south of Iceland had surface temperatures around 10-11°C, while it was considerably colder north of Iceland. The warm Atlantic water extended north beyond the 70 degrees in the eastern Norwegian Sea. The temperature distribution at 50m depth was similar as the surface layers but with cooler water, especially in the south-western Norwegian Sea, where the cold East Icelandic Current (EIC) and features like the Iceland-Faroe-Front (IFF) was clearly detected. South and west of the Iceland-Scotland Ridge, warm Atlantic water dominated the entire water column with temperature of 7-9°C at 400m depth. In the eastern Norwegian Sea warm Atlantic water was also detected down to 400m depth. In waters deeper than 100m the influence of the EIC is more pronounced and extends further south into Faroese and east into Norwegian waters

Zooplankton concentrations and distribution

The average plankton biomass increased from 6.0 g/m^2 in July-August 2012 to 8.6 g/m^2 over all stations throughout the survey area in July-August 2013 (Figure 2.5.3.2.4). The plankton concentrations were lowest in the central Norwegian Sea and highest in Faroese and Icelandic waters in addition to northern EU waters. The zooplankton samples for species identification have not been examined in detail.

The increased biomass of zooplankton is in agreement with the increase that has been observed in the zooplankton biomass in the Norwegian Sea in the May survey in 2013 after a decade with a decreasing trend in zooplankton biomass. These data need nevertheless to be treated with some care, due to various amounts of phytoplankton and salps between years and areas in the samples influencing the total amount of zooplankton (g dry weight/m^2) which is relevant and valuable as available food for pelagic planktivorous fish.

Spatial distribution of NEA mackerel

The mackerel was distributed in most of the surveyed area, and the zero boundaries were found in many areas, although not in the west in Greenland waters, south in the North Sea and west of the British Isles. The total mackerel catches (kg) taken during the joint ecosystem survey with the Multpelt 832 quantitative sampling trawl is presented in standardized rectangles in Figure 2.5.3.2.5. The map is showing different concentrations of mackerel from zero catch to more than 5000 kg.

Age distribution of NEA mackerel

The 2010 year class contributed to more than 20% in number followed by abundant 2006, 2007 and 2011-year classes around 15% each, respectively. The 2008 year class was also well represented in the catches, contributing with 12% of the total number (Figure 2.5.3.2.6).

Spatial overlap between pelagic fish species

The spatial distribution and overlap between the major pelagic fish species from the joint ecosystem survey in the Nordic Seas and surrounding coastal and offshore areas are shown in Figure 2.5.3.2.7. The spatiotemporal overlap between NEA mackerel and NSS herring in July-August 2013 was highest in the south-western part of the Norwegian Sea (Faroese, east Icelandic area and Jan Mayen waters). Herring were most densely aggregated in close relation to where we found the highest concentrations of zooplankton. Mackerel, on the other hand, were found over much larger areas and present in areas with varying zooplankton concentrations.

Abundance estimation and zonal distribution of NEA mackerel

The total swept area estimate of NEA mackerel in summer 2013 was 8.8 million tonnes based with coverage of 3.2 million square kilometers in the Nordic Seas from about 55.30 degrees up to 74.50 degrees north and from the Norwegian coast in east and west to the Irminger Sea in Greenland waters (Figure 2.5.3.2.8; Table 2.5.3.2.1).

The geographical coverage and survey effort in 2013 (3.2 mill km^2) was significantly larger than in 2012 (1.5 mill km^2) and in 2010 (1.7 mill km^2), while the coverage in 2011 was limited (1.1 mill km^2). In 2011 the northern part of the Norwegian Sea was not properly covered due to only one Norwegian vessel participating in the survey. The swept area biomass estimates of 4.8 million tonnes in 2010, 5.1 million tonnes estimate in 2012 may be compared with the biomass estimate of 8.8 million tonnes in 2013. These abundance estimates strongly suggest that the NEA mackerel have increased significantly both in geographical distribution and abundance. All these biomass estimates must be considered to be underestimations and only represent part of the stock.

Additionally, a master of science thesis has been written by Diaz (2013) entitled "schooling dynamics of summertime migrating northeast Atlantic mackerel (*Scomber scombrus*) in the Norwegian Sea using multibeam sonar". The schooling dynamics of NEA mackerel in nature is largely unknown because they lack a swimbladder, resulting in a weak acoustic signature, and therefore are difficult to detect in the summer when swimming in loose school formations. However, high frequency omnidirectional SONAR (SOund Navigation And Ranging) is capable of detecting NEA mackerel in the acoustic echosounder blind zone close to the surface. These results showed that there were regional differences in fish size, swimming speed and direction, school depth, temperature and zooplankton abundance. Mackerel were detected and caught where the temperature was above approximately 6° C. The thermocline depth had a profound influence on the depth distribution of schools throughout the Norwegian Sea during summer. NEA mackerel were consistently found shallower than 40 m depth both during day and night. The fish generally swam north except for in the SW region, coinciding well with prevailing current directions. Fish were significantly larger in the north than in the south, and plankton abundance was higher in the west than in the east. The observed school dynamics in relation to abiotic and biotic factors are explained in terms of the ecology of NEA mackerel during the summer feeding migration.

A comprehensive survey manual for the survey will be compiled in the coming months. It will be based on the methodology that has been evolved in recent years in this survey regarding the trawl and trawling procedure (e.g. Nøttestad et al. 2012) as well as manual from the IESNS survey in May in Norwegian Sea regarding acoustic, biological sampling, zooplankton and CTD. Large efforts will be made between the ICES WGWIDE meeting in August-September 2013 and NEA mackerel benchmark in February 2014 on these and other critical scientific issues.

Intercalibration and monitoring of trawl gear (Multipelt 832)

Comparative pelagic trawl hauls were conducted between the Norwegian vessels M/V "Libas" and M/V "Eros" 5-6 July 2013, and between R/V "Arni Fridriksson" and M/V "Finnur Friði" 15-16 July 2013. The Norwegian vessels had 4 comparative hauls while the Faroese and the Icelandic vessels had 8 comparative hauls. Two of the eight hauls (haul 2 and 3) conducted by the Icelandic and Faroese vessel were excluded due to bad transect lines during the trawling. In haul number 2 "Finnur Friði" was crossing the path of "Arni Fridriksson" which made "Arni Fridriksson" trawl in the propeller wake of "Finnur Fridi". In haul number 3, "Finnur Friði" had to make a sharp turn to avoid interfering with the trawl from "Arni Fridriksson". The Norwegian vessels conducted the hauls in an area with fairly high abundance of both mackerel and herring, while the Faroese and Icelandic vessels were trawling in an area with fairly high abundance of herring but low abundance of mackerel.

There was not a Gaussian distribution of the catches for any of the four vessels, and a non-parametric test had to be used to check if the catches were different. Both "Libas" and "Eros" are commercial vessels of similar size and fishing performance. The catches between these vessels were not significantly different for neither herring nor mackerel (t-test, $p>0.05$). "Arni Fridriksson" is a research vessel and "Finnur Friði" a commercial vessel. However, the catches between these vessels were also not significant different (Wilcox test, $p>0.05$). An important issue is the low number of comparative trawl hauls between the vessels, which reduce the probability to find significant difference in catchability between the vessels. Maps were made of the trawl hauls for all vessels and all comparative hauls onboard “Libas” and “Eros” and between “Arni Fridriksson” and “Finnur Friði”.

In recent years the pelagic trawl used in the IESSNS survey has been standardized but a standard method to monitor trawl performance has not been developed. In 2013, a trawl performance method was tested where trawl sensors were attached to the trawl at different locations. Performance of the pelagic trawl (Multipelt 832) was monitored at all stations on the Faroese vessel. Four pairs of fishing gear sensors recorded spread of trawl doors, under wings and trawl opening during trawling. Depth of ground rope was also reported. Recording frequency was every other second. Sensor performance was good at trawl doors and ground rope as data were recorded at all stations where as sensors at under wings and trawl opening recorded data at 70 % of stations. These results indicate trawl sensors provide a reliable method to monitor trawl performance during trawling. Detailed information on trawl performance during each haul is in Jacobsen and Olafsdottir (2013, WD to WGWIDE).

Ultimate goal

The ultimate goal is to get accepted and use this combined swept area estimate as an absolute/relative abundance index of spawning stock biomass (SSB) and possibly recruitment index, on an annual basis in the assessment of NEA mackerel after the NEA mackerel benchmark in February 2014. This will require allocation of survey time dedicated for inter-calibration between the participating vessels in future surveys.

A joint survey report from the 2013 Ecosystem surveys in the Nordic Seas and surrounding coastal and offshore waters from 2nd of July to 9th August (IESSNS) has been written and presented at the ICES WGWIDE meeting in Copenhagen, Denmark 27August – 2 September 2013 (Nøttestad *et al*. WD 2013).

2.5.3.3 Acoustic estimates of mackerel in the Iberian Peninsula and Bay of Biscay (PELACUS)

From 8th March to 5th April 2013 the acoustic survey PELACUS 0313 was carried out on board R/V Miguel Oliver. Although this was the first time this vessel was used and the intercalibration with R/V Thalassa (the former one), is expected to be done next year in May, given the similar main characteristics (i.e. a 70 m length stern trawler with diesel-electric power and fixed pitch propeller, within the standard ship underwater radiated noise as recommended in ICES CRR 209), results are considered to have been similar to those derived if R/V Thalassa had been used. Before the cruise, the ship was tested, including acoustic calibration, during a small survey performed in February in Galician waters. Moreover, additional effort was undertaken by increasing the length of the survey track up to 1000 isobath in order to cover the main distribution area of blue whiting.

The survey is an ecosystem survey and, therefore, several sampling devices are used and different species (including plankton, fish, marine mammals and birds), physical and chemical variables together with the fishing activity are studied. Among other fish species, mackerel, horse mackerel, blue whiting and boar fish are assessed acoustically. Survey objectives and strategies were already stated, although some changes have been made in order to improve mackerel estimates (see Carrera et al 2013, WD for further details).

A total of 3642 nautical miles were covered, 1080 of them corresponding to the survey track. Together with this, a total of 45 fishing station were performed. In IXa-N, due to the bad weather conditions, half of the transects were not surveyed and the rest, together with those located in the VIIIc-W Subdivision, have had to be sternway steamed to avoid bubbles sweep down. A total of 105.384,67 s_A were attributed to fish species. Due to the bad weather conditions and gear performance limitations to properly work close to the coast with hard and rough sea bed, 33% of the total backscattering energy (34.720,97 s_A) was not possible to allocate and therefore remained as unallocated, which mainly affected the coastal fish species (sardine, bogue, mediterranean horse mackerel).

Adult mackerel centre of gravity was located in the central part of the Cantabrian Sea (around 5º08'W with a s.d. of 60 nm and at 198 m depth), whereas the juvenile one was located westward (7º34'W with a s.d. of 44 nm and at 160 m depth). Horse mackerel, bogue and sardine centres were close to that of the adult mackerel centre; blue jack mackerel, blue whiting, chub mackerel and boar fish centres were close to the juvenile mackerel one. (Figure 2.5.3.3.1)

Total mackerel biomass estimate was 379 149 tonnes, corresponding to 1.725 million fish, 36 % higher than the previous year (244 809 t corresponding to 1 215 million fish). Juveniles (mainly age group 2, 38% of the total number) were located in VIIIc-West, and no school was observed in XIa-N. This result is consistent with that obtained the previous year when age class 1 was the most important. (Table 2.5.3.3.1 and 2.5.3.3.2); in contrast, the signal for age group 1 seems to be weak (Figure 2.5.3.3.2). This result also matches with that found in the Spanish Fall bottom trawl survey, DEMERSALES, where the mackerel abundance estimated (mainly from age group 0) was well below the average of the time series (1983-2012, Figure 2.5.3.3.3.a,b). However, due to the bad weather conditions found in southern areas (IXa-N), it could be possible that this age class (mainly located in this Division) would be inaccessible to the sampling gear.

On the other hand, mean weight-at-age derived from the acoustic surveys (i.e. spawning time for southern component) since 1990 has been reviewed (Villamor *et al* WD, 2013) together with those derived from the catch. There is a significant decreasing trend in mean weights-at-age for age class 4+. This reduction can be observed in both gutted weight and in the gonad weight for active maturity stages (3-4-5 from Walsh Scale) at spawning time. This trend should be monitored in order to check further changes in both spawning (i.e. changes in fecundity) and migration behaviour.

2.5.4 Tag Recaptures information

New and promising radio-frequency identification (RFID) tagging project on NEA mackerel has recently been launched at the Institute of Marine Research, Bergen (IMR) in Norway. The new RFID tagging project has moved away from manual and expensive to automatic and cost-effective systems.

RFID is a technology that uses radio waves to transfer data from an electronic tag, called RFID tag or label, attached to an object, through a reader for the purpose of identifying and tracking the object. Some RFID tags can be read from several meters away and beyond the line of sight of the reader. The application of bulk reading enables an almost parallel reading of tags.

IMR has been jigging and tagging mackerel on annual basis since 1968. Main tagging area has been west of Ireland and The British Isles. The tags used until 2011 were made of steel and injected into muscular tissues. All tagged fish has been length measured and manually noted on sheets, and punched/stored as a data file later on.

Tags have been recovered at metal detector/deflector gate systems installed at plants processing mackerel for human consumption. This system demanded a lot of manual work, paying for external personnel to stay at the plants during processing. Among the typical 50 fish deflected, the hired personal must find the tagged fish with a hand-hold detector and send the fish to IMR for analysis. This has been time consuming and expensive!

The tagging data have nevertheless been valuable for understanding the migration of the mackerel (Figure 2.5.4.1; see Tenningen *et al*. 2011).

The tagging data have also been used in estimates of mortality, and recently in estimation of spawning stock biomass (Figure 2.5.4.2; see Tenningen *et al*. 2011).

There is presently high uncertainty in spawning stock biomass (SSB) estimates in recent years, due to problems with our manually based detector systems. The major challenge is that this system is not screening sufficient number of catches.

Tenningen *et al*. (2011) recommended moving to automatic systems using Radio Frequency Identification (RFID)-technology, thereby increasing the screening and removing uncertainties caused by all the manual handling. ICES WGWIDE also recommended that IMR continued the tagging-program with RFID, with the aim to include this in future assessments.

In 2011 IMR initiated a new tagging project supported by The Fishery and Aquaculture Industry Research Fund (FHF) and Norwegian Sales Organisation for Pelagic Fish. Functions are to be finished in autumn 2012. 1: RFID tagging → 2: Database work → 3: RFID systems on eight different plants → 4: Software analysis, reports, other data, control of RFID systems → 5: Internet solution. A schematic illustration of how the radio frequency identification (RFID) tagging system works is shown in Figure 2.5.4.3.

The RFID-project run by the Institute of Marine Research (IMR) in Bergen, Norway is now fully operational and several countries have joined the tagging experiments and hooked up to the database served by IMR. RFID antenna and reader systems could be placed in any country landing mackerel and having plants using conveyor belts during processing. Cost of the system per date is approximately 120.000 NOK plus (~20 000 Euro). Transportation to plant and installation cost is additional. Also every system sends data to IMR database by GPRS and needs a SIM-card and a deal with a telephone company with minor annual costs. Cost of software needed and database will be zero. The web solution taking care of this will be served by IMR in Bergen. IMR could help out with training of personal with regard to the tagging process and data handling needed.

Estimating mackerel abundance and biomass with RFID data

The Institute of Marine Research (IMR) in Bergen started in 2011 using new tagging technology with RFID, and over the years 2011-2013 as many as 104835 mackerel has been tagged with the new tags. More the 100 of these tags has been returned by RFID antenna and reader systems at 8 factories along the Norwegian coast. Tagged fish are automatically recovered by these systems and updating a database at IMR at the same time. There is a web based software solution that is used to track the different systems, import data on catch information, and biological sampling data of released fish and screened catches. Based on this information the system can estimate numbers released and screened by year class in a known biomass landed, which is used to estimate abundance by year class and totally. The system is currently under quality checks of all data, fixing small errors etc, and hence estimates of abundance must still be handled as very preliminary. The plan is to have quality checked all the data and estimates prior to the mackerel benchmark in February 2014. It is also planned that the tagging data will be tested for inclusion in the SAM model during the autumn 2013.

There is one rule that will be followed with regard to the tagging data, and that is not start estimation of data the same year as the tagging. Data to estimate the abundance and biomass in the year of the tagging will be based on screening of commercial catches the year after and proceeding years. This means that for WGWIDE 2013, one can present estimates for the tagging year 2011 based on screened catches 2012-2013. In the Benchmark assessment in February 2014, estimates from the tagging year 2012 can be presented based on screening of catches in 2013. Very preliminary and uncertain data from the screening of catches during the autumn 2013 and January 2014 may also be used to look at estimates from the 2013 tagging year as an indication whether levels are increasing or decreasing.

The preliminary estimate of abundance, TSB and SSB based on the tagging at the spawning grounds of Ireland in 2011 indicate a very high population of NEA mackerel. When comparing with Tenningen *et al.* (2011), using the same initial tagging mortality of 40%, the estimates are in the order of 5-6 times higher than found around year 2000, clearly suggesting that the trend shown in Tenningen *et al*. (2011) with increasing SSB from 2000 to 2006 is something that may have evolved further. When the data is further analyzed and fully checked in the 2014 benchmark, we will now better and with more confidence the NEA mackerel stock level estimated from this methodology.

One reader system has recently been installed on Iceland by 1 September 2013. There are furthermore contracts for five reader systems in Scotland, two systems in Ireland and one system in Denmark. We also hope for contract with two reader systems in Faroe Islands. If more countries join in with increased number of screening systems, this could potentially lead to very good data for tracking migrations in addition to reducing uncertainty in the SSB-estimate.

The major aim for the RFID program is to get this method for abundance estimate on the SSB estimate to be included on an annual basis for NEA mackerel at the ICES WGWIDE assessment from 2014.

2.6 Stock Assessment

Since the last benchmark in 2007, NEA Mackerel has been classed as an update assessment. The assessment is carried out by fitting the integrated catch-at-age model (ICA, in the FLR environment - version 1.4-12 – 08 October 2009 15:16:26). The assessment model has a 12 year separable period, using the SSB estimates from the triennial mackerel egg survey as the tuning index. It uses data from 1972 – 2012 giving estimates of F from 1972 to 2012 and numbers-at-age from 1 Jan 1972 to 2013.

The new data used in this assessment compared to the assessment in 2012 are the 2012 catch-at-age, weights-at-age in the catch and in the stock, the updated maturity ogive and the 2013 SSB index provided by the 2013 mackerel egg survey. The input data are given in Tables 2.6.1-8.

2.6.1 Update assessment

The ICA model was run using the settings defined by the 2007 benchmark assessment (ICES CM 2007/ACFM:31) and described in the Stock Annex.

The results of the update assessment are given as the stock summary in Table 2.6.9 and Figure 2.6.1.1. The output values are in Tables 2.6.10-14. Run diagnostics are given in Tables 2.6.15–17 and Figures 2.6.1.2 and 2.6.1.3. The fitted parameter estimates of the assessment model are given in Table 2.6.18.

The assessment indicates SSB decreasing from 3.01 Mt in 2011 to 2.46 Mt in 2012. The fishing mortality F_{bar}4-8 is stable, estimated at 0.33 in 2012.

The fit to the mackerel egg survey data is very good for the years in the separable period. The diagnostics of the catch for the separable period do not show any pattern and the residuals are, in absolute value, quite small. Some cohort effects can be seen, showing a tendency of the model to underestimate the catch of young ages and underestimate the catch of old ages for particularly small cohorts (e.g. the year class 2000), the reverse holding for particularly large cohorts (e.g. the 2002 cohort).

This assessment, however, produces an unrealistic estimate of the 2012 recruitment, of about 100 times the historical level of recruitment. The estimates of terminal year recruitment are usually very uncertain – and replaced in the final assessment by a geometric mean - but not at such an order of magnitude.

In order to understand the source of the problem, the ICA model was run using the same settings, but excluding the 2013 SSB index. The output then was almost identical to the update run including the 2013 index, but the aberrant 2012 recruitment estimate was in the range of the historical recruitment time series. This indicates that the estimation of the numbers-at-age in the recent period by the ICA model including the 2013 survey index was not influenced by the new egg survey index, but only by the information from the catch-at-age matrix. The assessment shows a decline in SSB from 2011 to 2012, resulting from the combination of rather stable numbers-at-age with decreasing weights-at-age in the stock. The only possibility for the model to reconcile the declining SSB in 2012 with an increase in 2013 is to generate a massive recruitment for the 2012 year class, of which 6% will be mature in mature in 2013 and lead to the expected increase of SSB from 2012 to 2013. This behaviour of the model is a consequence of the very low weight given to the residuals from the age 0 catch (100 times lower than ages 2 and older and 300 times lower than any survey point). It results effectively in using the 2012 recruitment as a free parameter to obtain a perfect fit to the survey.

2.6.2 Exploratory runs

Different modifications of the ICA settings were then explored in order to constrain the 2012 recruitment estimate to a range of more realistic values.

Using a stock-recruitment relationship in the model

First, ICA was run using the option where estimated recruitments are constrained by a stock-recruitment relationship (a simple geometric mean recruitment) in the model. By doing so, deviations from a stock-recruitment relationship – fitted internally – are penalised, such that very large variations are not possible.

A sensitivity analysis was carried out to investigate the influence of the parameter lambda.SR - corresponding to the weight of the stock-recruitment function in the objective function of ICA - on the output of the model. This analysis indicated that a high lambda.SR value gave very stable recruitments over the separable period, while a low value for this parameter gave more variable recruitments, with, for very low lambda.SR values, the occurrence of very large and unrealistic recruitments in the recent years, as in the case of the update assessment.

It was decided to use the value lambda.SR = 0.17, for which the recruitment variability in the separable period in the current assessment was equal to the recruitment variability in last year's assessment.

The results of this assessment are given as the stock summary in Table 2.6.2.1 and Figure 2.6.2.1. The 2012 recruitment estimate is in the range of recruitment values historically observed. The 2011 recruitment is estimated at a similar value as the previous large year classes (2005 and 2006) and the 2010 year class appears to be exceptional (35% higher than the other large year classes). This assessment indicates a continuous increase of SSB from 2004 to 2011, with a maximum at 3.5 Mt, and a subsequent decrease in 2012 to 3.24 Mt. The fishing mortality Fbar(4-8) decreases from the historical maximum at 0.47 in 2003 and is estimated at 0.24 in 2012, close to F_{pa}.

Run diagnostics are given in Figures 2.6.2.2 and 2.6.2.3. Including a stock-recruitment function in the model results in a decrease in the fit to the egg survey index in the separable period compared to the update assessment. The catch residuals are not appreciably different from those in the update assessment.

Changing catch-at-age weighting

The second approach to avoid an unrealistically high 2012 recruitment was to increase the weighting on the catch-at-age residuals for ages 0 and 1. Weights for age 1 were increased to 0.33, the same as for age 2 and older, and weights for age 0 were increased to 0.033, representing for both ages a 10 fold increase compared to the update assessment. Increasing these weights penalises any large catch residuals, but this implies that the catch information for ages 0 and 1 is considered to be more reliable, which is debatable.

The results of this assessment are given as the stock summary in Table 2.6.2.2 and Figure 2.6.2.4. The trends in SSB and F are similar to those of the assessment using the stock-recruitment model, with the 2012 SSB estimated at 3.3 Mt and the 2012 F estimated at 0.23.

Run diagnostics are given in Figures 2.6.2.5 and 2.6.2.6. These ICA settings result in a deterioration of the fit to the egg survey index, with an overestimation of SSB in 2010 and an underestimation in 2013. The catch residuals are similar to the update assessment, except for large residuals for age 1 in the years 2002 to 2004.

The 2012 assessment was also run with modified weighting of the residuals of the young ages. This lead to very minor differences compared to the 2012 update assessment, accepted last year, which indicates that this modification of the weights does not create any major inconsistency.

Figures 2.6.2.7 and 2.6.2.8 show a comparison of the output of the assessments for the 3 different sets of settings in ICA. The two runs with modified ICA settings give a very comparable perception of the SSB, both indicating higher values in the recent years and narrower confidence intervals for the 2012 estimate than the update assessment.

2.6.3 Decision on the assessment

The Working Group decided to reject the update assessment, as well as the assessments using modified ICA settings. The decision was taken to classify the NEA mackerel stock as a Category 3 stock (in the ICES data limited stocks framework; IC-

ES 2012) for which the advice should be given on the basis of the trend in the mackerel egg survey index.

This decision was based on problems with the assessment that had previously been identified, on new information from industry (WKNAMMM 2013 - ICES CM 2013/SSGESST:18) and on new concerns about the assessment, arising from the problem encountered this year.

The assessment suffers both from the scarcity and the bad quality of the input data, the two main problems being that:

- Catches are underestimated by an unknown proportion, which is likely to have varied throughout the whole time series (ICES CM 2013/SSGESST:18). As a consequence, the assessment produces an underestimate of the NEA mackerel stock. It remains unclear to what extent changes in unaccounted catches affect the perception of the stock, provided by ICA, in the recent period. The sensitivity analysis presented in this WG report (Annex 3, Special requests) indicates that the level of misreporting in the past (pre-2005) has a strong influence on the stock size estimated for the recent years by the assessment, even if the trend seems to be rather insensitive.
- Changes in fishing practices undermine the principle of constant selectivity in the separable period
- The only independent index is not age based and is only available every three years. This implies that the estimated numbers-at-age in the most recent years are highly uncertain. This also implies that the perception of the stock might be significantly revised each time a new survey point is available.

The current model (ICA) relies on assumptions of correct catch and constant selectivity in the last 12 years (over the separable period). In the case of the NEA mackerel both assumptions are violated. In addition to this, there are clear indications of problems with the update assessment this year, which appears to be insensitive to the 2013 survey index (the only difference being the unrealistic 2012 recruitment when the 2013 index is used). This raised strong suspicions that we have come to a situation where ICA is not able to deal with the scarcity of information and the conflict between the catch data and the survey data. This technical problem of ICA could be overcome by modifying the settings, giving output more in agreement with the trend in the survey. However, the Working Group did not accept either of the two assessments based on modified settings, since the underlying problems with the model persist.

2.7 Short term forecast

Since there was no accepted assessment this year, no short term forecast is presented.

2.8 Basis of the advice

The NEA Mackerel has been classified as a category 3 – "*Stocks for which survey-based assessments indicate trends*", in the ICES data limited stocks classification.

Following ICES data limited stocks guidelines (ICES, 2012), the advised TAC should be based on a comparison of the two most recent index values with the three preceding values, combined with recent catch or landings data:

$$C_{y+1} = C_{y-1}\left(\frac{\sum_{i=y-x+1}^{y} I_i/x}{\sum_{i=y-z+1}^{y-x} I_i/(z-x)}\right)$$

Where y is the current year, I is the survey index, C_{y+1} is the advised TAC, C_{y-1} is the recent catch and x=2 and z=5.

Since the SSB index for NEA mackerel comes from a triennial egg survey, the working group decided to calculate the percentage change based on an interpolation of the egg survey time series. The method is illustrated on Figure 2.8.1. Using a simple linear interpolation between survey points, the ratio between the period 2012-2013 and 2009-2011 was equal to 1.23. Applying the uncertainty cap of 20% (i.e. maximum percentage change allowed), the catch multiplying factor was hence set at 1.20.

Since there is no trend in the catch over the 3 most recent years of data (2010 to 2012), the mean catch over these three years was used as a value for the recent catch, C_{y-1}.

In addition, a precautionary buffer of 20% is applied. This is felt to be especially relevant here because the advice is based on interpolation of triennial survey values and the 2013 survey estimate is preliminary.

This leads to an advised TAC for 2014 calculated as

$$advised\ TAC_{2014} = 1.20 \times 900\ 344\ t \times 0.80 \approx 864\ 300\ t$$

2.9 Comparison with previous assessment and forecast

Since there was no accepted assessment this year, no comparison with previous assessment is presented.

2.10 Management Considerations

Although a long term management plan was agreed by the EU, Norway and Faroe Islands in October 2008, it was not agreed by all parties involved in the fishery. Since 2008 there has been no TAC agreed by all parties. The absence of clear international agreements on the exploitation of the stock (between all nations involved in the fishery) is a cause of continued concern and prevents control of the exploitation rate of the stock.

Distribution and timing of migrations and spawning in recent years have resulted in the development of new fisheries and they have also had an impact on the operations of well-established fisheries. The information on variability in mackerel behaviour and distribution has been investigated in ICES Workshops (AGDMM; ICES 2013b).

There was no accepted assessment for mackerel in 2013. WGWIDE recommended that the basis for the advice be downgraded from a Category 1 to a Category 3 stock. WGWIDE did not provide an assessment based on model trends because of inconsistencies in the assessment model.

The advice for 2014 represents an increase in TAC compared to that advised in recent years. This is largely informed by the 2013 egg survey, which is consistent with additional sources of fishery independent data sets (including the swept area abundance estimate on NEA mackerel from the International Ecosystem Summer Survey in the Nordic Seas (IESSNS) that in 2013 indicates a very abundant mackerel stock).

WGWIDE supports an increase in 2014 catch based on the following:

- Mackerel SSB appears to be increasing consistently despite high catches taken from the stock;
- The stock has continuously expanded its geographical distribution during the summer (feeding) period since the mid-2000s (AGDMM, IESSNS Report 2013), potentially a sign of a large stock;
- Mean weight-at-age for adult fish is decreasing; although no direct causes have been determined, this would be likely related to both intra/interspecific competition on account the carrying capacity of the ecosystem
- Estimates from the IESSNS surveys of 2012 and 2013 indicate potentially strong year classes for both 2010 and 2011.

WGWIDE highlights the uncertainty associated with the following underlying processes which could call for a precautionary approach:

- There is insufficient understanding of the mechanisms driving the estimated increase in stock size;
- If the increase is the result of a high productivity regime the future duration of such a regime is unknown;
- The estimated increasing trend in biomass is based on a triennial survey. The 2013 result is preliminary and no uncertainty estimate is presently available. In addition to the sampling CV that is routinely computed there are additional sources of uncertainty such as: incomplete temporal and/or spatial coverage, consideration of stage 1 eggs only, assumptions about the starting and end point of mackerel spawning. Estimates of uncertainty from egg surveys are therefore likely to be under-represented;
- The egg survey gives no information on either the strength of recent year classes or of current age structure; as a result, a forecast of the stock trajectory is problematic.
- Swept area estimates, although showing an increasing trend, do not provide any CV estimation.

Concerns about the catch data have been raised in previous WGWIDE reports and by others (*e.g.* Simmonds *et al.*, 2010) regarding the likelihood of significant under-reporting as a consequence of undeclared catches, discards and slippage. Attempts by WGWIDE to determine the actual levels and the variability of these underestimates of the total removals have been unsuccessful. It is understood that such under reporting likely occurred, but the level and trend over time cannot be accurately estimated (WKNAMMM; ICES, 2013c; Annex 3).

Information on discarding and slipping of mackerel both in the past and at present is insufficient. Currently, discard information is provided by a few countries, but these do not represent a large proportion of the total catch. The observer programs for this fishery are inadequate. This is of concern and managers need to be aware that these data are needed in order to reduce uncertainty in the assessment.

There is an urgent need to implement new and more reliable quantitative data sets and time series on abundance indices for the NEA mackerel stock to provide a reliable assessment and scientific advice related to its exploitation. Amongst others, newly developed methods such as standardized swept area analyses from pelagic trawling in summer and the new radio frequency identification (RFID) tag-recapture technology will be presented and evaluated for implementation as future input data to the assessment model during the next benchmark assessment on NEA mackerel (scheduled for February 2014).

2.11 Ecosystem considerations

Identifying and measuring the most important physical and biological drivers for better understanding of the distribution, stock status and ecology of the NEA mackerel is not an easy task. Nevertheless, steady progress has been made during the last decades and it has resulted in increased knowledge. Temperature is usually the parameter which can most easily be measured accompanying the mackerel. Timing of overwintering, spawning migration and spawning of the NEA mackerel has previously been linked to temperature, with, e.g., earlier overwintering and spawning related to increased temperatures (Reid *et al*. 1997; Punzón & Villamor 2009; Jansen & Gislason 2011).

A forward shift in timing of spawning migration from April to March has been indicated during the last decade (Punzón and Villamor 2009). In winter 2011-2012 the timing of the spawning migration was even more pronounced in the Cantabrian Sea from early January to February compared to March and April just some years ago. This suggested a huge temporal shift of about two months, with an earlier spawning migration pattern of mackerel into the southern area in winter 2012 compared to earlier times, which might be linked to increased temperatures during winter and spring in the last few years. However, the triennial egg survey in 2013 showed that the peak of spawning in the Cantabrian Sea was later than in both 2007 and 2010.

It is likely that the picture is complex, and early spawning could also be linked to the accumulated experienced feeding situation for adult mackerel, since individuals may experience overall lower plankton concentrations now compared to earlier years. Measuring available planktonic food and actual feeding of mackerel is a much more comprehensive task than measuring temperature, but nevertheless a crucial task for improved understanding of mackerel ecology. In spring and summer 2012 the measurements of plankton concentrations were among the lowest in the entire time series since 1996 in the northern and western parts of the Northeast Atlantic. Limited food may possibly trigger earlier spawning migration and thus earlier spawning for NEA mackerel in different areas. The record high surface temperatures observed in the Nordic Seas during summer in recent years (Hughes *et al*. 2011; Nøttestad *et al*. 2012) compared to the long-term average have largely increased the potential feeding habitat for mackerel within their preferred "comfort" zone of above 6°C.

The mackerel seem to be very opportunistic, and from one year to the next they may exploit any available oceanic areas for feeding purposes (Langøy *et al.* 2012). A large spatial expansion of the mackerel stock has been measured by systematic and standardized pelagic trawling in the Nordic Seas in summers from 2007-2013. An abundant mackerel stock linked to density dependent processes possible through low densities of zooplankton may force the mackerel to spread out even more than ever recorded in the history of mackerel. Larger and older individuals generally migrate much longer distances during their search for available food compared to the juveniles and young adults (Nøttestad *et al*. 1999) and these patterns have been demonstrated every year for the NEA mackerel. Very high surface temperatures in the western part of the Nordic Seas in summer 2012 were also linked to a broader geographical expansion of large adult mackerel in the western and northwestern regions, now even including Greenland waters. In summer 2013 the sea surface temperature anomaly (SSTA) showed that the temperatures in the Nordic Seas were decreasing, and were now close to the long-term average compared to the last 20 years. However, in the northern and northeastern parts of the Norwegian Sea the surface waters in summer 2013 were significantly warmer compared to the long-term average for the region. Low density plankton concentrations spread more or less evenly over large ocean areas in the Nordic Seas in July-August 2013, combined with a record high and possibly increasing NEA mackerel stock, may force the mackerel to expand their feeding into formerly unknown mackerel areas to sustain their energetic needs during the feeding period. These results were verified by e.g. more mackerel entering the Irminger Sea and seeming to cover larger areas, and mackerel up north in the eastern part of Finnmark during the international coordinated IESSNS survey from 2nd of July to 9th of August 2013

Spatial and temporal overlap between NEA mackerel and NSS herring particularly in the outskirts or periphery of these waters (northern Faroese, Icelandic and Jan Mayen waters) in summer 2012 may indicate increased inter-specific competition between mackerel and herring for preferred food such as *Calanus finmarchicus* (Debes *et al*. 2012; Langøy *et al*. 2012; Oskarsson *et al*. 2012). Mackerel may partly out-compete herring during summer because mackerel are generally larger, faster, more enduring when migrating and more effective plankton eaters, including a wider food niche (wider diet breadth) than herring (Nøttestad *et al*. 2012). Mackerel may thus both compete better for preferred zooplankton species and size fractions as well as better utilize smaller plankton species available in the northern part of the Northeast Atlantic Ocean compared with herring.

Refer to Section 1.6 for further details of ecosystem concerns for the pelagic complex in the NE Atlantic

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Table 2.1.2.1. Catches in tonnes of *Scomber colias* in Divisions VIIIb, VIIIc and IXa in the period 1982 – 2012.

Subdivisions		**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**
VIIIb	Spain	0	0	0	0	0	0	0	0	0	487	7	4	427	247	778
VIIIc	Spain	322	254	656	513	750	1150	1214	3091	1923	1502	859	1892	1903	2558	2679
IXa N & S	Spain	0	0	0	0	0	0	0	0	0	0	895	3357	8573	5068	5437
IXa-CN, CS & S	Portugal	2458	1364	8059	9118	8184	8876	3816	6447	8568	10142	8981	7341	4430	3884	4759
Sub-Divisions		**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
VIIIb	Spain	362	1218	632	344	426	99	157	40	222	262	744	42	122	520	384
VIIIc	Spain	5026	1765	418	1905	1496	1509	2525	2741	3150	4260	7153	5203	3930	8939	17694
IXa N & S	Spain	2340	1381	983	1001	553	1566	981	888	812	2984	8239	8544	11860	12218	9152
IXa-CN, CS & S	Portugal	5408	6690	13877	10520	4228	5301	8030	14714	14905	13031	20222	23286	14428	22283	30635
Subdivisions		**2012**														
VIIIb	Spain	2089														
VIIIc	Spain	12068														
IXa N & S	Spain	13499														
IXa-CN, CS & S	Portugal	37191														

Table 2.2.1. 2012 Mackerel fleet composition of major mackerel catching nations.

Country	Len (m)	Engine power (Horse Power)	Gear	Storage	No vessels
Denmark	57-63	4077-8188	Trawl	Tank	5
	57-77	2475-6689	Purse Seine	Tank	6
Faroe Islands	56-90	1213-8000 kW	Purse Seine/Trawl	RSW/Freezer	9
France			Pelagic Trawl	Dry Hold	9
			Pelagic Trawl	Freezer	3
Germany	86-140	3600-12000	Single Midwater Trawl	Freezer	4
Iceland	6-15		Hooks	Fresh	51
	<50	470-2515	Single & Pair Midwater Trawl	Fresh./Freezer	41
	50-60	2300-4079	Single Midwater Trawl	Fresh/Freezer	13
	60-69	2998-7507	Single Midwater Trawl	Fresh/RSW/Freezer	12
	70-79	3308-11257	Single Midwater Trawl	RSW/Freezer	11
	>80	8051		Freezer	1
Ireland	13-58	160-2500	Midwater Trawl	Dryhold	3
	53-120	1007-6600	Midwater Trawl	RSW	4
	24-34	700-736	Pair Midwater Trawl	RSW	4
	27-71	670-3460	Pair Midwater Trawl	RSW	17
	16-37	171-1119	Pair Midwater Trawl	Dryhold	24
Netherlands	55	2890	Pair Midwater Trawl	Freezer	2
	88-145	4400-10455	Single Midwater Trawl	Freezer	1
Norway	>27		Purse Seine		80
	21-27		Purse Seine		17
	<21		Purse Seine		164
			Trawler		21
			Handline/Gillnet		155
Portugal	10-20		Trawl	Freezer	2
	20-30		Trawl	Freezer	7
	30-40		Trawl	Freezer	5
	0-10		Trawl	Other	259
	10-20		Trawl	Other	68
	20-30		Trawl	Other	60
	30-40		Trawl	Other	29
	0-10		Purse Seine	Other	79
	10-20		Purse Seine	Other	103
	20-30		Purse Seine	Other	79

Table 2.2.4. Overview of major existing regulations on mackerel catches

Technical measure	National/International level	Specification	Note
Catch limitation	Coastal States/NEAFC	2010, 2011, 2012: not agreed	
Management plan	European (EU, NO)	If SSB >= 2.200.000t, F = 0.2 to 0.22 If SSB is between 1.670.000t and 2.200.000t, F = 0.22 * SSB/2.200.000 TAC should not be changed more than 20% If SSB < 1.670.000t, parties shall decide on a TAC which is less than that arising from the calculation above	
Minimum size (North Sea)	European (EU, NO, Fo)	30cm in the North Sea	
Minimum size (all areas except North Sea)	European (EU, FO)	20cm in all areas except North Sea	10% undersized allowed
Minimum size	National (NO)	30cm in all areas	
Catch limitation	European (EU, NO, FO)	Within the limits of the quota for the western component (VI,VII, VIIIabde, Vb(EC), IIa(nonEC), XII, XIV), a certain quantity may be taken from IVa but only during the periods 1 January to 15 February and 1 October to 31 December.	
Area closure	National (UK)	South-West Mackerel Box off Cornwall	except where the weight of the mackerel does not exceed 15 % by liveweight of the total quantities of mackerel and other marine organisms onboard which have been caught in this area
Area limitations	National (IS)	Pelagic trawl fishery only allowed outside of 200m depth contours around Iceland and/or 12 nm from the coast.	
Quota adaptation	European (EU)	Reducing of Spanish mackerel quota with a scheduled payback until 2015 following the exceeding of fishing opportunities in 2010	
National catch limitations by gear, semester and area	National (ES)	30.5% of the Spanish national quota is assigned for the trawl fishery, 27.7% for purse seiners and 34.6% for the artisanal fishery	90,6 % of the Spanish national quota should be caught in ICES Div, IXa N and VIIIc. Besides, a 30.5% is assigned to the trawler fleet (8 tm as maximum daily catch per vessel), 27.7% to purse seiner (8 tm as maximum daily catch per vessel) and 34.6% to the artisanal fleet (2.3 tm as maximum daily catch per vessel); for all of them, a 7% of the catches should be kept for the second half of the year.
High-grading ban	European (EU)	High-grading (discarding fish of lower commercial value due to limited space on board) is banned in European water	
Discard prohibition	National (NO, IS, FO)	All discarding is prohibited for Norwegian, Icelandic and Faroese vessels	

Table 2.3.1.1. NE Atlantic Mackerel. Catches by area (t). Discards not estimated prior to 1978 (data submitted by Working Group members).

Year	Subarea VI			Subarea VII and Divisions VIIIabde			Subareas III and IV			Subareas I,II,V and XIV			Divisions VIIIc and IXa			Total		
	Ldg	Disc	Catch	Ldg	Disc	Catch	Ldg	Disc	Catch	Ldg	Disc	Catch	Ldg	Disc	Catch	Ldg	Disc	Catch
1969	4,800		4,800	47,404		47,404	739,175		739,175	7		7	42,526		42,526	833,912		833,912
1970	3,900		3,900	72,822		72,822	322,451		322,451	163		163	70,172		70,172	469,508		469,508
1971	10,200		10,200	89,745		89,745	243,673		243,673	358		358	32,942		32,942	376,918		376,918
1972	13,000		13,000	130,280		130,280	188,599		188,599	88		88	29,262		29,262	361,229		361,229
1973	52,200		52,200	144,807		144,807	326,519		326,519	21,600		21,600	25,967		25,967	571,093		571,093
1974	64,100		64,100	207,665		207,665	298,391		298,391	6,800		6,800	30,630		30,630	607,586		607,586
1975	64,800		64,800	395,995		395,995	263,062		263,062	34,700		34,700	25,457		25,457	784,014		784,014
1976	67,800		67,800	420,920		420,920	305,709		305,709	10,500		10,500	23,306		23,306	828,235		828,235
1977	74,800		74,800	259,100		259,100	259,531		259,531	1,400		1,400	25,416		25,416	620,247		620,247
1978	151,700	15,100	166,800	355,500	35,500	391,000	148,817		148,817	4,200		4,200	25,909		25,909	686,126	50,600	736,726
1979	203,300	20,300	223,600	398,000	39,800	437,800	152,323	500	152,823	7,000		7,000	21,932		21,932	782,555	60,600	843,155
1980	218,700	6,000	224,700	386,100	15,600	401,700	87,931		87,931	8,300		8,300	12,280		12,280	713,311	21,600	734,911
1981	335,100	2,500	337,600	274,300	39,800	314,100	64,172	3,216	67,388	18,700		18,700	16,688		16,688	708,960	45,516	754,476
1982	340,400	4,100	344,500	257,800	20,800	278,600	35,033	450	35,483	37,600		37,600	21,076		21,076	691,909	25,350	717,259
1983	320,500	2,300	322,800	235,000	9,000	244,000	40,889	96	40,985	49,000		49,000	14,853		14,853	660,242	11,396	671,638
1984	306,100	1,600	307,700	161,400	10,500	171,900	43,696	202	43,898	98,222		98,222	20,208		20,208	629,626	12,302	641,928
1985	388,140	2,735	390,875	75,043	1,800	76,843	46,790	3,656	50,446	78,000		78,000	18,111		18,111	606,084	8,191	614,275
1986	104,100		104,100	128,499		128,499	236,309	7,431	243,740	101,000		101,000	24,789		24,789	594,697	7,431	602,128
1987	183,700		183,700	100,300		100,300	290,829	10,789	301,618	47,000		47,000	22,187		22,187	644,016	10,789	654,805
1988	115,600	3,100	118,700	75,600	2,700	78,300	308,550	29,766	338,316	120,404		120,404	24,772		24,772	644,926	35,566	680,492
1989	121,300	2,600	123,900	72,900	2,300	75,200	279,410	2,190	281,600	90,488		90,488	18,321		18,321	582,419	7,090	589,509
1990	114,800	5,800	120,600	56,300	5,500	61,800	300,800	4,300	305,100	118,700		118,700	21,311		21,311	611,911	15,600	627,511

Table 2.3.1.1. NE Atlantic Mackerel. Catches by area (t). Continued.

Year	Subarea VI			Subarea VII and Divisions VIIIabde			Subareas III and IV			Subareas I,II,V and XIV			Divisions VIIIc and IXa			Total		
	Ldg	Disc	Catch	Ldg	Disc	Catch	Ldg	Disc	Catch	Ldg	Disc	Catch	Ldg	Disc	Catch	Ldg	Disc	Catch
1991	109,500	10,700	120,200	50,500	12,800	63,300	358,700	7,200	365,900	97,800		97,800	20,683		20,683	637,183	30,700	667,883
1992	141,906	9,620	151,526	72,153	12,400	84,553	364,184	2,980	367,164	139,062		139,062	18,046		18,046	735,351	25,000	760,351
1993	133,497	2,670	136,167	99,828	12,790	112,618	387,838	2,720	390,558	165,973		165,973	19,720		19,720	806,856	18,180	825,036
1994	134,338	1,390	135,728	113,088	2,830	115,918	471,247	1,150	472,397	72,309		72,309	25,043		25,043	816,025	5,370	821,395
1995	145,626	74	145,700	117,883	6,917	124,800	321,474	730	322,204	135,496		135,496	27,600		27,600	748,079	7,721	755,800
1996	129,895	255	130,150	73,351	9,773	83,124	211,451	1,387	212,838	103,376		103,376	34,123		34,123	552,196	11,415	563,611
1997	65,044	2,240	67,284	114,719	13,817	128,536	226,680	2,807	229,487	103,598		103,598	40,708		40,708	550,749	18,864	569,613
1998	110141	71	110,212	105,181	3,206	108,387	264,947	4,735	269,682	134,219		134,219	44,164		44,164	658,652	8,012	666,664
1999	116,362		116,362	94,290		94,290	313,014		313,014	72,848		72,848	43,796		43,796	640,311		640,311
2000	187,595	1	187,595	115,566	1,918	117,484	285,567	165	304,898	92,557		92,557	36,074		36,074	736,524	2,084	738,608
2001	143,142	83	143,142	142,890	1,081	143,971	327,200	24	339,971	67,097		67,097	43,198		43,198	736,274	1,188	737,462
2002	136,847	12,931	149,778	102,484	2,260	104,744	375,708	8,583	394,878	73,929		73,929	49,576		49,576	749,131	23,774	772,905
2003	142,728	91	142,819	89,492		89,492	334,639	9,390	357,766	53,701		53,701	25,823		25,823	660,119	9,481	669,600
2004	134,251	240	134,491	99,922	1,862	101,784	300,768	8,870	316,620	62,486		62,486	34,840		34,840	639,248	10,972	650,221
2005	79,960	11,400	91,361	90,278	5,878	96,156	249,740	2,482	252,223	54,129		54,129	49,618		49,618	523,726	19,760	543,486
2006	88,077	6,031	94,108	66,209	6,556	72,765	200,929	5,383	206,312	46,716		46,716	52,751		52,751	454,682	17,970	472,652
2007	110,788	405	111,193	71,235	2,024	73,259	253,013	6,187	259,200	72,891		72,891	62,834		62,834	570,761	8,616	579,379
2008	76,358	21,793	98,151	73,377	1,987	75,364	227,251	2,986	230,237	148,669		148,669	59,859		59,859	584,297	26,766	611,063
2009	135,468	1,255	136,723	88,287	4,387	92,674	226,928	7,212	234,140	163,604		163,604	107,747		107,747	732,034	12,854	734,889
2010	106,732	114	106,846	104,127	3,723	107,850	246,817	14	246,831	355,724	5	355,729	49,068	3,126	52,194	862,470	6,981	869,451
2011	160,756	1,633	162,389	50,699	6,027	56,726	301,746	790	302,536	370,761		370,761	18,430	562	19,037	929,807	9,012	938,819
2012	121,115	26	121,141	65,720	10,965	76,685	218,400	540	218,940	447,207		447,207	24,940	3,849	28,789	877,382	15,380	892,762

Table 2.3.2.1. NE Atlantic Mackerel. Catch (t) in the Norwegian Sea (IIa) and Area V 1984–2012 (Data submitted by Working Group members).

Country	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
Denmark	11,787	7,610	1,653	3,133	4,265	6,433	6,800	1,098	251	
Estonia									216	
Faroe Islands	137				22	1,247	3,100	5,793	3,347	1,167
France		16				11		23	6	6
Germany, Fed. Rep.			99		380					
Germany, Dem. Rep.			16	292		2,409				
Iceland										
Ireland										
Latvia									100	4,700
Lithuania										
Netherlands										
Norway	82,005	61,065	85,400	25,000	86,400	68,300	77,200	76,760	91,900	100,500
Poland										
Sweden										
United Kingdom			2,131	157	1,413		400	514	802	
USSR/Russia	4,293	9,405	11,813	18,604	27,924	12,088	28,900	13,361	42,440	49,600
Misreported (IVa)										
Misreported (VIa)										
Misreported (Ukn)										
Unallocated										
Discards										
Total	98,222	78,096	101,112	47,186	120,404	90,488	118,700	97,819	139,062	165,973

Table 2.3.2.1. NE Atlantic Mackerel. Catch (t) in the Norwegian Sea (IIa) and Area V 1984–2012. Continued.

Country	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Denmark		4,746	3,198	37	2,090	106	1,375	7	1	
Estonia	3,302	1,925	3,741	4,422	7,356	3,595	2,673	219		
Faroe Islands	6,258	9,032	2,965	5,777	2,716	3,011	5,546	3,272	4,730	
France	5	5		270						
Germany										
Greenland			1							
Iceland			92	925	357				53	122
Ireland						100				495
Latvia	1,508	389	233							
Lithuania							2,085			
Netherlands			561			661			569	
Norway	141,114	93,315	47,992	41,000	54,477	53,821	31,778	21,971	22,670	12,548[1]
Poland				22						
Sweden								8		
United Kingdom	1,706	194	48	938	199	662		54	665	510
Russia	28,041	44,537	44,545	50,207	67,201	51,003	49,100[1]	41,566	45,811	40,026
Misreported (IVa)	-109,625	-18,647			-177	-40,011				
Misreported (VIa)						-100				
Misreported (Ukn)									-570	
Unallocated										
Discards										
Total	72,309	135,496	103,376	103,598	134,219	72,848	92,557	67,097	73,929	53,701

Table 2.3.2.1. NE Atlantic Mackerel. Catch (t) in the Norwegian Sea (IIa) and Area V 1984–2012. Continued.

Country	2004	2005	2006	2007	2008	2009	2010	2011	2012
Denmark							4,845	269	
Estonia									
Faroe Islands	650	30		278	123	2,992	66,312	121,499	107,198
France	2	1							
Germany				7				2	107
Greenland								62[1]	5,284[1]
Iceland		363	4,222	36,706	112,286	116,160[1]	121,008[1]	159,263[1]	149,282[1]
Ireland	471							90	
Latvia									
Lithuania									
Netherlands	34	2,393			72		90	178	5
Norway	10,295	13,244	8,914	493	3,474	3,038	104,858	43,168	110,741
Poland									
Sweden									4
United Kingdom	1,945				4				
Russia	49,489	40,491	33,580	35,408	32,728	41,414[1]	58,596	73,601	74,587
Misreported (IVa)									
Misreported (VIa)									
Misreported (Ukn)	-400								
Unallocated		-2,393		-10	-18				
Discards							2		
Total	62,486	54,129	46,716	72,882	148,669	163,604	355,711	398,132	447,207

1 – included catches in area XIVb

Table 2.3.2.2. NE Atlantic Mackerel. Catch (t) in the North Sea, Skagerrak and Kattegat (Sub-area IV and IIIa) 1988-2012 (Data submitted by Working Group members).

Country	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Belgium	20	37		125	102	191	351	106	62	114
Denmark	32,588	26,831	29,000	38,834	41,719	42,502	47,852	30,891	24,057	21,934
Estonia					400					
Faroe Islands		2,685	5,900	5,338		11,408	11,027	17,883	13,886	3,288[2]
France	1,806	2,200	1,600	2,362	956	1,480	1,570	1,599	1,316	1,532
Germany, Fed. Rep.	177	6,312	3,500	4,173	4,610	4,940	1,497	712	542	213
Iceland										
Ireland		8,880	12,800	13,000	13,136	13,206	9,032	5,607	5,280	280
Latvia					211					
Netherlands	2,564	7,343	13,700	4,591	6,547	7,770	3,637	1,275	1,996	951
Norway	59,750	81,400	74,500	102,350	115,700	112,700	114,428	108,890	88,444	96,300
Poland										
Romania							2,903			
Sweden	1,003	6,601	6,400	4,227	5,100	5,934	7,099	6,285	5,307	4,714
United Kingdom	1,002	38,660	30,800	36,917	35,137	41,010	27,479	21,609	18,545	19,204
USSR (Russia from 1990)										3,525
Misreported (IIa)							109,625	18,647		
Misreported (VIa)	180,000	92,000	126,000	130,000	127,000	146,697	134,765	106,987	51,781	73,523
Misreported (Unknown)										
Unallocated	29,630	6,461	-3,400	16,758	13,566			983	236	1,102
Discards	29,776	2,190	4,300	7,200	2,980	2,720	1,150	730	1,387	2,807
Total	338,316	281,600	305,100	365,875	367,164	390,558	472,397	322,204	212,839	229,487

Table 2.3.2.2. NE Atlantic Mackerel. Catch (t) in the North Sea, Skagerrak and Kattegat (Sub-area IV and IIIa) 1988-2012. Continued.

Country	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007[1]
Belgium	125	177	146	97	22	2	4	1	3	1
Denmark	25,326	29,353	27,720	21,680	34,375[1]	27,508[1]	25,665	23,212[1]	24,219[1]	25,217[1]
Estonia										
Faroe Islands	4,832	4,370	10,614	18,751	12,548	11,754	11,705	9,739	12,008	11,818
France	1,908	2,056	1,588	1,981	2,152	1,467	1,538	1,004	285	7,549
Germany	423	473	78	4,514	3,902	4,859	4,514	4,442	2,389	5,383
Iceland		357								
Ireland	145	11,293	9,956	10,284	20,715	17,145	18,901	15,605	4,125	13,337
Latvia										
Netherlands	1,373	2,819	2,262	2,441	11,044	6,784	6,366	3,915	4,093	5,973
Norway	103,700	106,917	142,320	158,401	161,621	150,858	147,069	106,434	113,079	131,191
Poland								109		
Romania										
Sweden	5,146	5,233	4,994[1]	5,090	5,232[1]	4,450	4,437	3,204	3,209	3,858[1]
United Kingdom	19,755	32,396	58,282	52,988	61,781	51,736	50,474	37,118	28,628	46,264
Russia	635	345	1,672	1				4		
Misreported (IIa)		40,000								
Misreported (VIa)	98,432	59,882	8,591	39,024	49,918	46,407	18,480	37,911	8,719	
Misreported (Ukn)										
Unallocated	3,147	17,344	34,761	24,873	22,985	25,405	18,597	7,043	171	2,421
Discards	4,753		1,912	24	8,583	9,390	8,870	2,482	5,383	6,187
Total	269,700	313,015	304,896	339,970	394,878	357,765	316,620	252,223	206,311	259,199

Table 2.3.2.2. NE Atlantic Mackerel. Catch (t) in the North Sea, Skagerrak and Kattegat (Subarea IV and IIIa) 1988-2012. Continued.

Country	2008[1]	2009[1]	2010[1]	2011[1]	2012[1]
Belgium	2	3	27	21	39
Denmark	26,716	23,491	36,552	32,808	36,492
Estonia					
Faroe Islands	7,627	6,648	4,639	543	432
France	490	1,493	686	1,416	5,736
Germany	4,668	5,158	2,562[1]	5,291[1]	4,560
Iceland					
Ireland	11,628	12,901	14,639	15,811	20,422
Latvia					
Netherlands	1,980	2,039	1,300	10,663	6,018
Norway	114,102	118,070	129,064	162,878	64,181
Poland					
Romania					
Sweden	3,664[1]	7,303[1]	3,428[1]	3,248[1]	4,560
United Kingdom	37,055	47,863	52,563	69,858	75,959
Russia			696		
Misreported (IIa)					
Misreported (VIa)	17,280	1,959			
Misreported (Ukn)					
Unallocated	2,039	-629	660		
Discards	2,986	7,212	14	790	540
Total	230,237	234,140	246,830	302,536	218,940

[1]-includes small catches in IIIb,c,d

Table 2.3.2.3. NE Atlantic Mackerel. Catch (t) in the Western area (Sub-areas VI and VII and Divisions VIIIa,b,d,e) 1985–2012 (Data submitted by Working Group members).

Country	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**
Belgium										
Denmark	400	300	100		1,000		1,573	194		2,239
Estonia										
Faroe Islands	9,900	1,400	7,100	2,600	1,100	1,000				4,283
France	7,400	11,200	11,100	8,900	12,700	17,400	4,095		2,350	9,998
Germany	11,800	7,700	13,300	15,900	16,200	18,100	10,364	9,109	8,296	25,011
Guernsey										
Ireland	91,400	74,500	89,500	85,800	61,100	61,500	17,138	21,952	23,776	79,996
Isle of Man										
Jersey										
Lithuania										
Netherlands	37,000	58,900	31,700	26,100	24,000	24,500	64,827	76,313	81,773	40,698
Norway	24,300	21,000	21,600	17,300	700		29,156	32,365	44,600	2,552
Poland									600	
Spain				1,500	1,400	400	4,020	2,764	3,162	4,126
United Kingdom	205,900	156,300	200,700	208,400	149,100	162,700	162,588	196,890	215,265	208,656
Misreported (Area IVa)		-148,000	-117,000	-180,000	-92,000	-126,000	-130,000	-127,000	-146,697	-134,765
Misreported (Unknown)										
Unallocated	75,100	49,299	26,000	4,700	18,900	11,500	-3,802	1,472		4,632
Discards	4,500			5,800	4,900	11,300	23,550	22,020	15,660	4,220
Total	467,700	232,599	284,100	197,000	199,100	182,400	183,509	236,079	248,785	251,646

Table 2.3.2.3. NE Atlantic Mackerel. Catch (t) in the Western area (Sub-areas VI and VII and Divisions VIIIa,b,d,e) 1985–2012. Continued.

Country	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Belgium										1
Denmark	1,143	1,271			552	82	835		392	
Estonia	361									
Faroe Islands	4,284		2,448[1]	3,681	4,239	4,863	2,161	2,490	2,260	674
France	10,178	14,347	19,114	15,927	14,311	17,857	18,975	19,726	21,213	18,549
Germany	23,703	15,685	15,161	20,989	19,476	22,901	20,793	22,630	19,202	18,730
Guernsey										
Ireland	72,927	49,033	52,849	66,505	48,282	61,277	60,168	51,457	49,715	41,730
Isle of Man										
Jersey										
Lithuania										
Netherlands	34,514	34,203	22,749	28,790	25,141	30,123	33,654	21,831	23,640	21,132
Norway			223							
Poland										
Spain	4,509	2,271	7,842	3,340	4,120	4,500	4,063	3,483	735	2,081
United Kingdom	190,344	127,612	128,836	165,994	127,094	126,620	139,589	131,599	130,762	122,311
Misreported (Area IVa)	-106,987	-51,781	-73,523	-98,255	-59,982	-3,775	-39,024	-43,339	-46,407	-18,049
Misreported (Unknown)										
Unallocated	28,245	10,603	4,577	8,351	21,652	31,564	37,952	27,558	33,767	27,999
Discards	6,991	10,028	16,057	3,277		1,920	1,164	15,191	91	2,102
Total	270,212	213,272	196,110	218,599	204,885	297,932	280,553	252,620	235,370	237,260

Table 2.3.2.3. NE Atlantic Mackerel. Catch (t) in the Western area (Sub-areas VI and VII and Divisions VIIIa,b,d,e) 1985–2012. Continued.

Country	2005	2006	2007	2008	2009	2010	2011	2012
Belgium					1	2		
Denmark			6	10		48	2,889	8
Estonia								
Faroe Islands		59	1,333	3,539	4,421	36	8	
France	15,182	14,625	12,434	14,944	16,464	10,301	11,304	14,448
Germany	14,598	14,219	12,831	10,834	17,545	16,493	18,792	14,277
Guernsey		10					10	5
Ireland	30,082	36,539	35,923	33,131	48,155	43,355	45,711	42,627
Isle of Man						14		11
Jersey	9	8	6	7	8	6	7	
Lithuania		95	7				23	
Netherlands	18,819	20,064	18,261	17,920	20,900	21,699	23,659	19,794
Norway			7	3,948	121	30	2,019	1,101
Poland	461		978					
Spain	4,795	4,048	2,772	7,327	8,462	6,532	3,578	773
United Kingdom	115,683	67,187	87,424	76,306[1]	109,147	107,840	111,114	93,775
Misreported (Area IVa)	-37,911	-8,719		-17,280	-1,959			
Misreported (Unknown)								
Unallocated	8,521	4,783	10,042	-952	490	4,503		16
Discards	17,278	12,587	2,428	23,780	5,642	3,837	7,660	10,991
Total	187,517	166,873	184,452	173,514	229,397	214,696	219,115	197,826

Table 2.3.2.4. NE Atlantic Mackerel. Catch (t) in Divisions VIIIc and IXa, 1977–2011 (Data submitted by Working Group members).

Country	Div	1977	1978	1979	1980	1981	1982	1983	1984	1985
France	VIIIc									
Poland	IXa	8								
Portugal	IXa	1,743	1,555	1,071	1,929	3,108	3,018	2,239	2,250	4,178
Spain	VIIIc	19,852	18,543	15,013	11,316	12,834	15,621	10,390	13,852	11,810
Spain	IXa	2,935	6,221	6,280	2,719	2,111	2,437	2,224	4,206	2,123
USSR	IXa	2,879	189	111						
Total	IXa	7,565	7,965	7,462	4,648	5,219	5,455	4,463	6,456	6,301
Total		27,417	26,508	22,475	15,964	18,053	21,076	14,853	20,308	18,111

Country	Div	1986	1987	1988	1989	1990	1991	1992	1993	1994
France	VIIIc									
Poland	IXa									
Portugal	IXa	6,419	5,714	4,388	3,112	3,819	2,789	3,576	2,015	2,158
Spain	VIIIc	16,533	15,982	16,844	13,446	16,086	16,940	12,043	16,675	21,246
Spain	IXa	1,837	491	3,540	1,763	1,406	1,051	2,427	1,027	1,741
USSR	IXa									
Total	IXa	8,256	6,205	7,928	4,875	5,225	3,840	6,003	3,042	3,899
Total		24,789	22,187	24,772	18,321	21,311	20,780	18,046	19,719	25,045

Country	Div	1995	1996	1997	1998	1999	2000	2001	2002	2003
France	VIIIc									226
Poland	IXa									
Portugal	IXa	2,893	3,023	2,080	2,897	2,002	2,253	3,119	2,934	2,749
Spain	VIIIc	23,631	28,386	35,015	36,174	37,631	30,061	38,205	38,703	17,381
Spain	IXa	1,025	2,714	3,613	5,093	4,164	3,760	1,874	7,938	5,646
Discards	VIIIc									
Discards	IXa	3,918	5,737	5,693	7,990	6,165	6,013			
Total	IXa	27,549	34,123	40,708	44,164	43,796	36,074	4,993	10,873	8,395
Total								43,198	49,575	26,002

Table 2.3.2.4. NE Atlantic Mackerel. Catch (t) in Divisions VIIIc and IXa, 1977–2012 (Data submitted by Working Group members). Continued..

Country	Div	2004	2005	2006	2007	2008	2009	2010	2011	2012
France	VIIIc	177	151	43	55	168	383	392	44	283
Poland	IXa									
Portugal	IXa	2,289	1,509	2,620	2,605	2,381	1,753	2,363	962	824
Spain	VIIIc	28,428	42,851	43,063	53,401	50,455	91,043	38,858	14,709	17,768
Spain	IXa	3,946	5,107	7,025	6,773	6,855	14,569	7,455	2,759	1,253
Discards	VIIIc							1,704	292	2,187
Discards	IXa							1,422	270	1,661
Unallocated	VIIIc									4,144
Unallocated	IXa									1,076
Total	IXa	6,234	6,616	9,645	9,378	9,236	16,322	11,240	3,991	4,406
Total		34,840	49,618	52,751	62,834	59,859	107,748	52,194	19,036	28,789

Table 2.3.3.1. NE Atlantic Mackerel. Catch numbers ('000s) -at-age by area for 2012.

Quarters 1-4

Age	IIIa	IIIb	IIIc	IIId	IVa	IVb	IVc	VIId
0	46				683522	190		
1	29315	136	100	27	19732973	102763	162766	3656462
2	211831	852	498	82	66194192	2441546	689522	7657188
3	287815	1283	441	152	72094076	1188841	303831	5228404
4	432294	2000	602	247	132821892	967773	247428	4008712
5	340091	1420	611	153	109915562	1222335	192268	1129937
6	235903	850	534	71	97759271	897771	163921	1545074
7	103421	342	260	24	52653860	477568	40815	585457
8	11026	37	28	3	20010085	274593	21311	72607
9	45700	148	114	10	11587668	171915	13205	24437
10	31502	102	78	7	6047254	87672	5893	
11	831	3	3		1047991	67303	5893	
12	577	1	1		670629	33545	2946	
13	192	1	1		892708	242		
14	709	2	2		498762	580		
15+	682	2	2		71085	386		
SOP	617.2	2.6	1.1	0.3	217512.7	2315.0	475.4	6217.2
Ctch	614.6	2.6	1.1	0.3	215534.1	2314.1	473.2	6138.7
SOP%	99.6%	98.3%	100.2%	99.4%	99.1%	100.0%	99.5%	98.7%

Age	**VIIa**	**VIIb**	**VIIc**	**VIIe**	**VIIf**	**VIIg**	**VIIh**	**VIIj**	**VIIk**
0		26024	41940	853433	5379	29460	796275	225064	17111
1	34753	248672	638759	600949	881504	1149976	1895352	4258151	244298
2	28823	31577075	348885	817414	661711	615761	1229443	3221002	124483
3	7344	19415586	359421	1045817	136786	533020	1077103	7741198	126042
4	11190	12706539	1552267	650560	127279	675408	1089817	15900478	196531
5	6473	17907374	1960901	27130	36465	245515	346897	17312167	119511
6	11540	16381990	1712312	33806	51488	341486	479788	22289212	157934
7	5022	5715276	1059188	128990	30455	114019	196261	12630855	77235
8	1819	2596163	397822	60434	9146	36236	69080	6755946	27476
9	1232	740366	283441		841	12218	19808	2864028	8048
10	1444	391077	143871	103	6866	3500	8004	1644805	7986
11	423	44494	81674	103	7089	2446	3894	559879	1314
12	35	459	57476		232	2767	4363	332935	1562
13	1	52	38		103	86	173	144048	37
14	27	16931	157						
15+		56			128	38	108	177876	6
SOP	25.0	26576.9	2943.3	865.9	324.6	669.9	1306.6	31214.8	245.7
Ctch	25.0	26587.3	2946.6	865.9	324.7	679.1	1318.0	31235.1	248.0
SOP%	100.0%	100.0%	100.1%	100.0%	100.0%	101.4%	100.9%	100.1%	101.0%

Table 2.3.3.1. NE Atlantic Mackerel. Catch numbers ('000s) -at-age by area for 2012 (cont)

Quarters 1-4

Age	VIIIa	VIIIb	VIIIc	VIIIcE	VIIIcW	VIIId	IXaCN	IXaN	IXaS
0	2463596	1818	1611530	3180	17272	10	7388812	208062	6106701
1	1495755	590336	4594680	955824	346680	312	1243346	1625694	4284085
2	1319784	674804	303436	2201661	6512560	64600	1426708	682422	1313482
3	879856	237614	1001596	2058789	4460873	183184	522910	461822	374424
4	439928	246180	1018466	4360014	2790911	1645961	457359	332427	150680
5	389798	741299	937284	7881450	2267318	1518875	290691	350413	104264
6	1689127	2351294	896250	15235475	2039767	1572409	253929	1002153	213236
7	519731	1023450	779435	11715004	991245	584741	74243	868910	168582
8	259866	508426	367199	4225620	237407	271062	39588	323107	56571
9	129933	267045	202466	2626740	104133	115096	25360	155990	23230
10	129933	170978	83833	852676	54031	42538	30524	54362	6879
11		26992	34523	333840	19049	112	199573	22730	2927
12	129933	155590	11416	115772	9424	58	8	5881	482
13		5809	9090	120540	8360	28	7	4889	446
14									
15+						28			
SOP	2166.5	2191.6	2172.7	17464.4	4552.4	1984.2	1589.3	1505.2	1428.7
Ctch	2166.3	2178.4	2187.5	17618.2	4577.3	1971.5	1590.9	1511.7	1303.7
SOP	100.0%	99.4%	100.7%	100.9%	100.5%	99.4%	100.1%	100.4%	91.3%

Age	IIa	IIb	Va	Vb	VIa	VIb	XIVb	Total
0	253997		5473722	11608	721	9459		26228931
1	16211186	40	770947		1180867	48480	37572	67022758
2	48780082	387	9085200	1303505	13842100	18625	187856	203537516
3	38456372	418	28721964	3843581	22797207	14638	2189559	215751966
4	102667002	1726	59375027	9810338	54754027	16199	5585541	415042800
5	127143603	2050	67612190	14624394	72207820	4670	5902706	452743634
6	149453690	2879	80519177	10600655	94545251	6212	6975559	509420013
7	126933742	3375	41421605	7861754	52176844	1490	3656850	322600047
8	66035887	1982	16547690	4794867	18255481	455	1189714	143458733
9	29862655	801	8139861	3436118	8497690	51	707570	70067917
10	10807939	257	3651894	1178364	4789055	4	198286	30431714
11	5759570	179	953581	683833	2020492	4	112714	11993457
12	3377470	60	925136	665732	604865	1	75142	7184499
13	798397	21	231284	394706	1		37572	2648830
14	677717	17	154189	137338	426031		75142	1987604
15+	72053	1		12	2			322465
SOP	281658.5	5.7	131191.9	23683.5	121084.8	18.6	11630.3	895642.6
Ctch	281691.2	5.7	130184.0	23693.3	121122.0	18.9	11633.0	892762.1
SOP%	100.0%	99.9%	99.2%	100.0%	100.0%	101.5%	100.0%	99.7%

Table 2.3.3.1. NE Atlantic Mackerel. Catch numbers ('000s) -at-age by area for 2012 (cont)

Quarter 1

Age	IIIa	IIIb	IIIc	IIId	IVa	IVb	IVc	VIId
0								
1	95				2831			
2	193				18893	16229	2334	1214137
3	160				23582	6858	778	880504
4	216				40414	741	467	547991
5	229				50901	5823		
6	204				55384	2963	156	67817
7	100				29357	1399	156	166257
8	12				7756	747		49220
9	43				7563	7		
10	30				4438	3		
11	1				766	3		
12	1				309	2		
13								
14	1				228			
15+	1				65			
SOP	0.4				83.1	8.1	0.8	727.2
Ctch	0.4				83.1	8.2	0.8	688.5
SOP%	98.2%				100.0%	100.2%	100.1%	94.7%

Age	VIIa	VIIb	VIIc	VIIe	VIIf	VIIg	VIIh	VIIj	VIIk
0									
1		188711	558874		62916	1088715	1328232	3854050	210485
2	1	30983015	333273	135402	49566	601073	776521	3129252	116207
3	2	19091527	340533	372356	16289	508520	744908	7052050	98326
4	1	12606643	1439235	236954	13196	596765	818253	13902913	115407
5		17818975	1728589		2544	168611	223155	15470938	32644
6		16280795	1373620		3524	226445	295906	18493277	43842
7		5678983	627451	67701	3299	51936	97683	9861823	10089
8		2576319	176938	33851	1141	11703	29571	3957298	2286
9		728987	102542			1921	3064	1617312	382
10		380919	53949		480	155	2644	1277986	36
11		43356	22222		480	153	186	540	30
12		8	15202			48	59	171	9
13									
14		16863	157						
15+									
SOP	0.0	26319.8	2143.3	222.0	26.8	529.8	742.7	24996.5	102.5
Ctch	0.0	26329.0	2145.4	222.0	26.8	537.2	751.8	25015.2	103.9
SOP%	117.0%	100.0%	100.1%	100.0%	100.0%	101.4%	101.2%	100.1%	101.4%

Table 2.3.3.1. NE Atlantic Mackerel. Catch numbers ('000s) -at-age by area for 2012 (cont)

Quarter 1

Age	VIIIa	VIIIb	VIIIc	VIIIcE	VIIIcW	VIIId	IXaCN	IXaN	IXaS
0									
1		117549	3532342	130288	108272		340479	561177	252710
2		381535	189398	1489612	6112446	62080	455558	487910	46482
3		76011	971219	1665267	3989476	180999	175566	379323	10458
4		105029	990813	4017701	2457342	1644215	103492	264438	375
5	261404	650190	895949	7648595	2031834	1517610	147187	304930	433
6	1132750	2265611	837721	15011356	1832285	1570923	78737	934132	1325
7	348539	967023	740341	11582948	855309	583833	57029	811636	1151
8	174269	483405	357248	4172547	174088	270451	34556	295786	420
9	87135	259717	198737	2608360	75621	114788	12227	150561	214
10	87135	168304	82255	846186	39649	42446	17305	52761	75
11		25862	34002	331062	12395		10645	22053	31
12	87135	155094	11219	114609	7724		6	5770	8
13		5356	8973	119452	7263		5	4786	7
14									
15+									
SOP	742.7	753.5	1893.1	1808.2	16804.5	4013.3	307.7	1211.9	30.2
Ctch	751.8	753.5	1896.1	1820.2	16985.2	4034.9	307.7	1216.2	28.1
SOP	101.2%	100.0%	100.2%	100.7%	101.1%	100.5%	100.0%	100.4%	93.0%

Age	IIa	IIb	Va	Vb	VIa	VIb	XIVb	Total
0								
1					191548	29032		12558304
2					9546535	16029		56163679
3					20375426	13560		56973699
4					48318752	15913		88237265
5					68160957	4496		117125993
6					86735745	6038		147250554
7					49520004	1385		82065430
8					17071730	312		29881652
9					7503786	51		13473017
10					3671177	4		6727935
11					1958714	4		2462505
12					604670	1		1002045
13								145842
14					425944			443192
15+								65
SOP					109596.7	14.1		194317.1
Ctch					109630.2	14.3		194567.0
SOP%					100.0%	101.4%		100.1%

Table 2.3.3.1. NE Atlantic Mackerel. Catch numbers ('000s) -at-age by area for 2012 (cont)

Quarter 2

Age	IIIa	IIIb	IIIc	IIId	IVa	IVb	IVc	VIId
0								
1	16963	62	73	19	46898	16871	41916	1036283
2	104524	126	40	38	313153	1591421	238869	3070977
3	105299	104	6	32	376637	748788	113529	1608918
4	143550	141	6	43	615228	271779	64588	1394898
5	150545	149	8	45	545810	692007	57211	397331
6	133271	133	9	41	495481	527331	56543	590251
7	64581	65	5	20	243379	380848	36165	214397
8	6584	8	3	2	51123	235803	19952	
9	29202	28		9	105124	156163	11785	
10	20153	19		6	51506	83139	5893	
11	411				1051	65158	5893	
12	411				4439	32766	2946	
13					6776			
14	411				1051	375		
15+	411				1051	375		
SOP	259.1	0.3	0.0	0.1	900.4	1333.1	171.2	2115.8
Ctch	259.2	0.3	0.0	0.1	900.7	1337.2	170.0	2076.4
SOP%	100.0%	97.9%	103.3%	99.0%	100.0%	100.3%	99.3%	98.1%

Age	VIIa	VIIb	VIIc	VIIe	VIIf	VIIg	VIIh	VIIj	VIIk
0									
1	15499	1703	8815	6728	402802	12922	20035	49285	7513
2	11847	562344	4414	110940	300449	6491	10031	29262	3762
3	3080	309623	13754	292252	58085	20247	31451	658089	25548
4	3977	60474	108912	186281	55608	74837	116343	1969632	78903
5	3572	70445	229985	272	16766	74363	115441	1825900	85617
6	4350	47977	336870	377	24273	112560	175461	3780728	113076
7	2433	18767	428602	53173	14066	59309	92819	2746643	65324
8	756	11003	218694	26532	4868	22573	36172	2781467	23932
9	329	3278	180548		841	9842	15809	1242504	7418
10	300	1282	89570	51	3248	3047	4838	364224	7735
11	225	463	59452	51	3470	2222	3707	558397	1265
12	32	349	42275		232	2677	4304	332213	1541
13		7	38		103	67	173	143802	32
14	26	69							
15+					128	15	108	177572	
SOP	10.0	174.7	778.1	176.1	146.9	122.9	192.3	6087.8	133.6
Ctch	10.0	175.1	779.6	176.1	146.9	125.1	195.8	6095.4	134.9
SOP%	100.0%	100.2%	100.2%	100.0%	100.0%	101.8%	101.8%	100.1%	101.0%

Table 2.3.3.1. NE Atlantic Mackerel. Catch numbers ('000s) -at-age by area for 2012 (cont)

Quarter 2

Age	VIIIa	VIIIb	VIIIc	VIIIcE	VIIIcW	VIIId	IXaCN	IXaN	IXaS
0							16259		
1		11610	30961	32859	5279	112	14298	333499	1160260
2		189202	24221	535492	319228	2452	19260	93881	632268
3		105366	13553	298215	452070	2111	7500	45373	235882
4		90706	20320	256722	297573	1569	4628	26510	115600
5	128395	69014	39973	195329	206172	1138	5182	22106	92517
6	556377	69438	57461	196530	188236	1093	3668	48428	201935
7	171193	32011	35973	90601	116412	585	2368	37157	156933
8	85596	9330	7798	26406	44921	200	1216	11290	47788
9	42798	5216	3729	14764	28512	121	498	5429	23016
10	42798	1707	1578	4831	14381	53	584	1600	6804
11		751	520	2126	6654	24	1319	677	2896
12	42798	275	197	777	1700	7	2	111	474
13		275	117	779	1097	5	2	103	439
14									
15+									
SOP	370.1	133.7	64.5	378.3	426.6	2.3	16.0	94.5	454.0
Ctch	370.1	134.7	64.9	381.2	428.6	2.3	15.2	94.0	441.2
SOP	100.0%	100.8%	100.6%	100.8%	100.5%	100.6%	95.1%	99.5%	97.2%

Age	IIa	IIb	Va	Vb	VIa	VIb	XIVb	Total
0								16259
1					35			3273298
2	2540836		527690	864651	2061			12109930
3	3963130		5593560	2168835	5897		10430	17267364
4	8097318		10342809	4978881	16628		62580	29457043
5	7272257		10870504	3286526	20303		229459	26704341
6	9926177		10131732	3154726	28551		250319	31213401
7	6590824		3799399	1574944	16867		125159	17171020
8	4353848		1899700	692725	5093		62580	10687963
9	2871447		738772	604134	2127		31290	6134733
10	1389356		105539	1563	1253		10430	2217488
11	639720		105539	1563	563			1464117
12	394949			65911	139			931525
13	80650			131821				366285
14	139650				78			141661
15+	23000							202660
SOP	17520.6		15467.2	4837.5	35.0		349.0	52751.4
Ctch	17531.2		15467.0	4839.3	35.0		349.0	52736.4
SOP%	100.1%		100.0%	100.0%	100.0%		100.0%	100.0%

Table 2.3.3.1. NE Atlantic Mackerel. Catch numbers ('000s) -at-age by area for 2012 (cont)

Quarter 3

Age	IIIa	IIIb	IIIc	IIId	IVa	IVb	IVc	VIId
0								
1	10808	74	26	8	853609	72017	65341	1665165
2	102012	726	450	44	9438652	746986	404270	2614223
3	171839	1179	413	121	13769413	334551	135636	1811838
4	272770	1859	564	204	21999829	514996	165604	1777327
5	182358	1271	591	107	16777910	396230	129585	638457
6	99248	718	523	31	11240083	263733	101803	793758
7	37305	277	254	4	5021804	41070	3623	189812
8	3933	29	25	1	852996	16568		
9	16107	120	114	1	1926232	6502		
10	11099	83	78	1	1247767	1643		
11	390	3	3		71493	920		
12	134	1	1		27680	294		
13	134	1	1		17242			
14	268	2	2		31169	37		
15+	268	2	2		28821			
SOP	340.2	2.4	1.0	0.2	30500.9	714.0	252.7	2502.4
Ctch	337.6	2.3	1.0	0.2	30333.0	711.1	251.6	2502.4
SOP%	99.2%	98.3%	100.2%	99.6%	99.4%	99.6%	99.6%	100.0%

Age	VIIa	VIIb	VIIc	VIIe	VIIf	VIIg	VIIh	VIIj	VIIk
0		721	14272	234005	5	10524	21192	88372	8361
1	19221	2819	14187	218141	341199	10461	30536	87842	8311
2	16898	9547	3605	239235	255622	2810	20221	22439	2112
3	4232	4523	1981	159985	50261	1918	13246	13125	1172
4	7139	15004	3284	116713	47794	3125	14985	22366	1957
5	2801	6846	1818	26858	14272	2207	6331	12994	1089
6	7054	20592	1314	33429	19696	2146	6465	12872	855
7	2480	7029	2826	8116	10846	2571	5276	20972	1725
8	1000	3759	1772	51	2594	1685	2631	15264	1127
9	875	3323	352			455	522	4211	248
10	1135	3438	352	51	2594	298	522	2596	215
11	197	364		51	2594	71		942	20
12		101				42		551	12
13		45				19		246	5
14									
15+		56				23		304	6
SOP	14.8	28.1	8.9	205.7	123.3	8.3	27.5	63.7	5.4
Ctch	14.8	28.1	8.1	205.7	123.3	7.7	26.3	58.6	4.9
SOP%	100.0%	99.8%	90.8%	100.0%	100.0%	92.7%	95.5%	92.0%	91.2%

Table 2.3.3.1. NE Atlantic Mackerel. Catch numbers ('000s) -at-age by area for 2012 (cont)

Quarter 3

Age	VIIIa	VIIIb	VIIIc	VIIIcE	VIIIcW	VIIId	IXaCN	IXaN	IXaS
0	1951356	1618	1522206	2841	6814		3024570	132503	4952038
1	1184752	193749	948853	340198	92115		758778	639429	2281827
2	1045369	7505	77435	13178	34305		813149	83963	514289
3	696913	2447	14830	4297	9304	50	286871	26127	107032
4	348456	3719	5818	6529	16848	148	211649	24325	30276
5		2243	1085	3939	13724	106	89020	12797	10141
6		1595	683	2801	9212	380	101719	11449	9073
7		2268	2573	3983	8764	307	11122	12131	9613
8		1858	1768	3262	8093	397	950	9663	7657
9		673		1182		187	8543		
10		352		617		39	8543		
11		184		323		88	184728		
12		157		275		52			
13		140		245		23			
14									
15+						28			
SOP	826.1	35.8	277.1	62.8	48.8	0.7	909.1	152.7	761.5
Ctch	826.0	32.2	279.3	56.5	49.3	0.7	911.6	153.9	675.2
SOP	100.0%	90.1%	100.8%	90.1%	101.0%	100.6%	100.3%	100.8%	88.7%

Age	IIa	IIb	Va	Vb	VIa	VIb	XIVb	Total
0	252973		5472052		721			17697142
1	14705417		770712		16363		37572	25369526
2	41371529	290	8554899	380816	21917		187856	66986353
3	32611156	381	23121348	1520909	15164		2179129	77071389
4	90914081	1637	49017258	4522493	29357		5522961	175621074
5	114631492	1929	56724374	10779980	31691		5673247	206177492
6	134458593	2721	70365970	6818241	27237		6725240	231139232
7	115842658	3247	37610727	5743235	14072		3531691	168152379
8	58313891	1907	14643521	3641694	5738		1127134	78670967
9	24519463	764	7398831	2480505	1722		676280	37047212
10	8396368	245	3545273	1013056	846		187856	14425063
11	4102579	175	847783	554335	155		112714	5880109
12	2559576	57	924854	517580	50		75142	4106557
13	701361	20	231213	251277	1		37572	1239543
14	525778	16	154142	125730	8		75142	912294
15+	48028	1		12	2			77553
SOP	250798.1	5.4	115689.5	17351.4	55.5		11282.3	433056.2
Ctch	250828.3	5.4	114682.0	17357.9	55.1		11284.0	431814.0
SOP%	100.0%	100.0%	99.1%	100.0%	99.4%		100.0%	99.7%

Table 2.3.3.1. NE Atlantic Mackerel. Catch numbers ('000s) -at-age by area for 2012 (cont)

Quarter 4

Age	IIIa	IIIb	IIIc	IIId	IVa	IVb	IVc	VIId
0	46				683522	190		
1	1449		1		18829636	13875	55509	955013
2	5102		7		56423494	86911	44049	757850
3	10517		22		57924444	98645	53889	927144
4	15758		32		110166421	180258	16769	288497
5	6959		12		92540941	128274	5472	94148
6	3180		3		85968323	103744	5420	93249
7	1436		1		47359319	54251	871	14992
8	496				19098210	21475	1359	23387
9	348				9548749	9244	1420	24437
10	221				4743543	2888		
11	29				974681	1223		
12	31				638201	482		
13	58				868690	242		
14	30				466314	168		
15+	3				41149	12		
SOP	17.5		0.0		186019.2	259.9	50.7	871.5
Ctch	17.4		0.0		184217.2	257.6	50.7	871.5
SOP%	99.5%		96.3%		99.0%	99.1%	100.0%	100.0%

Age	VIIa	VIIb	VIIc	VIIe	VIIf	VIIg	VIIh	VIIj	VIIk
0		25303	27668	619428	5375	18936	775083	136692	8750
1	34	55440	56884	376081	74586	37878	516550	266974	17989
2	78	22170	7593	331836	56074	5387	422669	40049	2401
3	30	9913	3152	221224	12151	2334	287497	17933	997
4	74	24418	836	110612	10680	680	140236	5568	264
5	100	11108	509		2884	335	1971	2335	161
6	136	32626	509		3995	335	1956	2335	161
7	109	10498	309		2243	203	483	1417	98
8	62	5082	418		544	275	706	1918	132
9	28	4777					413		
10	9	5438			544				
11	1	311			544				
12	2								
13	1								
14	1								
15+									
SOP	0.2	54.9	13.2	262.2	27.7	9.0	343.9	64.8	4.2
Ctch	0.3	55.1	13.5	262.2	27.7	9.2	344.2	66.0	4.3
SOP%	100.4%	100.4%	102.0%	100.0%	100.0%	101.9%	100.1%	101.8%	102.0%

Table 2.3.3.1. NE Atlantic Mackerel. Catch numbers ('000s) -at-age by area for 2012 (cont)

Quarter 4

Age	VIIIa	VIIIb	VIIIc	VIIIcE	VIIIcW	VIIId	IXaCN	IXaN	IXaS
0	512240	201	89325	339	10458	10	4347983	75559	1154663
1	311003	267428	82524	452480	141015	201	129791	91590	589287
2	274414	96562	12383	163380	46580	68	138741	16668	120443
3	182943	53789	1995	91009	10023	23	52973	10998	21052
4	91472	46727	1516	79061	19147	30	137590	17153	4429
5		19851	277	33588	15589	20	49303	10579	1173
6		14650	385	24788	10034	13	69805	8144	903
7		22147	548	37473	10760	16	3725	7986	886
8		13833	385	23406	10305	13	2867	6368	706
9		1439		2434			4092		
10		616		1042			4092		
11		195		330			2882		
12		65		110					
13		38		65					
14									
15+									
SOP	216.8	129.2	22.9	218.6	63.5	0.1	356.3	46.2	183.0
Ctch	216.8	115.4	23.1	195.3	64.5	0.1	356.4	47.7	159.2
SOP	100.0%	89.3%	101.1%	89.3%	101.5%	97.6%	100.0%	103.1%	87.0%

Age	IIa	IIb	Va	Vb	VIa	VIb	XIVb	Total
0	1024		1670	11608		9459		8515530
1	1505769	40	235		972923	19447		25821630
2	4867716	96	2611	58038	4271588	2596		68277553
3	1882087	37	7056	153838	2400720	1078		64439515
4	3655603	89	14960	308964	6389290	286		121727418
5	5239854	121	17312	557889	3994869	174		102735808
6	5068920	158	21475	627688	7753718	174		99816826
7	4500260	128	11479	543575	2625901	106		55211218
8	3368148	75	4469	460447	1172919	143		24218150
9	2471745	38	2258	351478	990054			13412955
10	1022215	13	1082	163746	1115780			7061227
11	1017271	4	259	127936	61061			2186727
12	422946	4	282	82241	8			1144372
13	16386	1	71	11608				897160
14	12289	1	47	11608	1			490458
15+	1024							42187
SOP	13333.0	0.3	35.3	1495.6	11405.2	4.5		215509.5
Ctch	13331.7	0.3	35.0	1496.2	11401.7	4.6		213644.7
SOP%	100.0%	99.2%	99.1%	100.0%	100.0%	101.9%		99.1%

Table 2.3.3.2. NE Atlantic Mackerel. Percentage catch numbers-at-age by area for 2012. Zeros represent values <1%.

Quarters 1-4

Age	IIIa	IIIb	IIIc	IIId	IVa	IVb	IVc	VIId
0	0%				0%	0%		
1	2%	2%	3%	3%	3%	1%	9%	15%
2	12%	12%	15%	11%	11%	31%	37%	32%
3	17%	18%	13%	20%	12%	15%	16%	22%
4	25%	28%	18%	32%	22%	12%	13%	17%
5	20%	20%	19%	20%	19%	15%	10%	5%
6	14%	12%	16%	9%	16%	11%	9%	6%
7	6%	5%	8%	3%	9%	6%	2%	2%
8	1%	1%	1%	0%	3%	3%	1%	0%
9	3%	2%	3%	1%	2%	2%	1%	0%
10	2%	1%	2%	1%	1%	1%	0%	
11	0%	0%	0%	0%	0%	1%	0%	
12	0%	0%	0%	0%	0%	0%	0%	
13	0%	0%	0%		0%	0%		
14	0%	0%	0%	0%	0%	0%		
15+	0%	0%	0%	0%	0%	0%		

Age	VIIa	VIIb	VIIc	VIIe	VIIf	VIIg	VIIh	VIIj	VIIk
0	0%	0%	0%	20%	0%	1%	11%	0%	2%
1	32%	0%	7%	14%	45%	31%	26%	4%	22%
2	26%	29%	4%	19%	34%	16%	17%	3%	11%
3	7%	18%	4%	25%	7%	14%	15%	8%	11%
4	10%	12%	18%	15%	7%	18%	15%	17%	18%
5	6%	17%	23%	1%	2%	7%	5%	18%	11%
6	10%	15%	20%	1%	3%	9%	7%	23%	14%
7	5%	5%	12%	3%	2%	3%	3%	13%	7%
8	2%	2%	5%	1%	0%	1%	1%	7%	2%
9	1%	1%	3%		0%	0%	0%	3%	1%
10	1%	0%	2%	0%	0%	0%	0%	2%	1%
11	0%	0%	1%	0%	0%	0%	0%	1%	0%
12	0%	0%	1%		0%	0%	0%	0%	0%
13	0%	0%	0%		0%	0%	0%	0%	0%
14	0%	0%	0%						
15+	0%	0%			0%	0%	0%	0%	0%

Table 2.3.3.2. NE Atlantic Mackerel. Percentage catch numbers-at-age by area for 2012. Zeros represent values <1% (cont)

Quarters 1-4

Age	VIIIa	VIIIb	VIIIc	VIIIcE	VIIIcW	VIIId	IXaCN	IXaN	IXaS
0	25%	0%	14%	0%	0%	0%	62%	3%	48%
1	15%	8%	39%	2%	2%	0%	10%	27%	33%
2	13%	10%	3%	4%	33%	1%	12%	11%	10%
3	9%	3%	8%	4%	22%	3%	4%	8%	3%
4	4%	4%	9%	8%	14%	27%	4%	5%	1%
5	4%	11%	8%	15%	11%	25%	2%	6%	1%
6	17%	34%	8%	29%	10%	26%	2%	16%	2%
7	5%	15%	7%	22%	5%	10%	1%	14%	1%
8	3%	7%	3%	8%	1%	5%	0%	5%	0%
9	1%	4%	2%	5%	1%	2%	0%	3%	0%
10	1%	2%	1%	2%	0%	1%	0%	1%	0%
11		0%	0%	1%	0%	0%	2%	0%	0%
12	1%	2%	0%	0%	0%	0%	0%	0%	0%
13		0%	0%	0%	0%	0%	0%	0%	0%
14									
15+						0%			

Age	IIa	IIb	Va	Vb	VIa	VIb	XIVb	All
0	0%	0%	2%	0%	0%	8%		1%
1	2%	0%	0%		0%	40%	0%	3%
2	7%	3%	3%	2%	4%	15%	1%	8%
3	5%	3%	9%	6%	7%	12%	8%	9%
4	14%	12%	18%	17%	16%	13%	21%	17%
5	17%	14%	21%	25%	21%	4%	22%	18%
6	21%	20%	25%	18%	27%	5%	26%	21%
7	17%	24%	13%	13%	15%	1%	14%	13%
8	9%	14%	5%	8%	5%	0%	4%	6%
9	4%	6%	3%	6%	2%	0%	3%	3%
10	1%	2%	1%	2%	1%	0%	1%	1%
11	1%	1%	0%	1%	1%	0%	0%	0%
12	0%	0%	0%	1%	0%	0%	0%	0%
13	0%	0%	0%	1%	0%		0%	0%
14	0%	0%	0%	0%	0%		0%	0%
15+	0%	0%		0%	0%			0%

Table 2.3.3.2. NE Atlantic Mackerel. Percentage catch numbers-at-age by area for 2012. Zeros represent values <1% (cont)

Quarter 1

Age	IIIa	IIIb	IIIc	IIId	IVa	IVb	IVc	VIId
0								
1	7%				1%			
2	15%				8%	47%	60%	41%
3	12%				10%	20%	20%	30%
4	17%				17%	2%	12%	19%
5	18%				21%	17%		
6	16%				23%	9%	4%	2%
7	8%				12%	4%	4%	6%
8	1%				3%	2%		2%
9	3%				3%	0%		
10	2%				2%	0%		
11	0%				0%	0%		
12	0%				0%	0%		
13								
14	0%				0%			
15+	0%				0%			

Age	VIIa	VIIb	VIIc	VIIe	VIIf	VIIg	VIIh	VIIj	VIIk
0									
1		0%	8%		41%	33%	31%	5%	33%
2	15%	29%	5%	16%	32%	18%	18%	4%	18%
3	44%	18%	5%	44%	11%	16%	17%	9%	16%
4	28%	12%	21%	28%	9%	18%	19%	18%	18%
5		17%	26%		2%	5%	5%	20%	5%
6		15%	20%		2%	7%	7%	24%	7%
7	8%	5%	9%	8%	2%	2%	2%	13%	2%
8	5%	2%	3%	4%	1%	0%	1%	5%	0%
9		1%	2%			0%	0%	2%	0%
10		0%	1%		0%	0%	0%	2%	0%
11		0%	0%		0%	0%	0%	0%	0%
12		0%	0%			0%	0%	0%	0%
13									
14		0%	0%						
15+									

Table 2.3.3.2. NE Atlantic Mackerel. Percentage catch numbers-at-age by area for 2012. Zeros represent values <1% (cont)

Quarter 1

Age	VIIIa	VIIIb	VIIIc	VIIIcE	VIIIcW	VIIId	IXaCN	IXaN	IXaS
0									
1		2%	40%	0%	1%		24%	13%	81%
2		7%	2%	3%	35%	1%	32%	11%	15%
3		1%	11%	3%	23%	3%	12%	9%	3%
4		2%	11%	8%	14%	27%	7%	6%	0%
5	12%	11%	10%	15%	11%	25%	10%	7%	0%
6	52%	40%	9%	30%	10%	26%	5%	22%	0%
7	16%	17%	8%	23%	5%	10%	4%	19%	0%
8	8%	9%	4%	8%	1%	5%	2%	7%	0%
9	4%	5%	2%	5%	0%	2%	1%	4%	0%
10	4%	3%	1%	2%	0%	1%	1%	1%	0%
11		0%	0%	1%	0%		1%	1%	0%
12	4%	3%	0%	0%	0%		0%	0%	0%
13		0%	0%	0%	0%		0%	0%	0%
14									
15+									

Age	IIa	IIb	Va	Vb	VIa	VIb	XIVb	All
0								
1					0%	33%		2%
2					3%	18%		9%
3					6%	16%		9%
4					15%	18%		14%
5					22%	5%		19%
6					28%	7%		24%
7					16%	2%		13%
8					5%	0%		5%
9					2%	0%		2%
10					1%	0%		1%
11					1%	0%		0%
12					0%	0%		0%
13								0%
14					0%			0%
15+								0%

Table 2.3.3.2. NE Atlantic Mackerel. Percentage catch numbers-at-age by area for 2012. Zeros represent values <1% (cont)

Quarter 2

Age	IIIa	IIIb	IIIc	IIId	IVa	IVb	IVc	VIId
0								
1	2%	7%	48%	7%	2%	0%	6%	12%
2	13%	15%	27%	15%	11%	33%	36%	37%
3	14%	12%	4%	12%	13%	16%	17%	19%
4	18%	17%	4%	17%	22%	6%	10%	17%
5	19%	18%	5%	18%	19%	14%	9%	5%
6	17%	16%	6%	16%	17%	11%	9%	7%
7	8%	8%	4%	8%	9%	8%	6%	3%
8	1%	1%	2%	1%	2%	5%	3%	
9	4%	3%		3%	4%	3%	2%	
10	3%	2%		2%	2%	2%	1%	
11	0%	0%		0%	0%	1%	1%	
12	0%	0%		0%	0%	1%	0%	
13					0%			
14	0%	0%		0%	0%	0%		
15+	0%	0%		0%	0%	0%		

Age	VIIa	VIIb	VIIc	VIIe	VIIf	VIIg	VIIh	VIIj	VIIk
0									
1	33%	0%	1%	1%	46%	3%	3%	0%	2%
2	26%	52%	0%	16%	34%	2%	2%	0%	1%
3	7%	28%	1%	43%	7%	5%	5%	4%	6%
4	9%	6%	6%	28%	6%	19%	19%	12%	19%
5	8%	6%	13%	0%	2%	19%	18%	11%	20%
6	9%	4%	20%	0%	3%	28%	28%	23%	27%
7	5%	2%	25%	8%	2%	15%	15%	16%	15%
8	2%	1%	13%	4%	1%	6%	6%	17%	6%
9	1%	0%	10%		0%	2%	3%	7%	2%
10	1%	0%	5%	0%	0%	1%	1%	2%	2%
11	0%	0%	3%	0%	0%	1%	1%	3%	0%
12	0%	0%	2%		0%	1%	1%	2%	0%
13		0%	0%		0%	0%	0%	1%	0%
14	0%	0%							
15+					0%	0%	0%	1%	

Table 2.3.3.2. NE Atlantic Mackerel. Percentage catch numbers-at-age by area for 2012. Zeros represent values <1% (cont)

Quarter 2

Age	VIIIa	VIIIb	VIIIc	VIIIcE	VIIIcW	VIIId	IXaCN	IXaN	IXaS
0							21%		
1		2%	13%	2%	0%	1%	19%	53%	43%
2		32%	10%	32%	19%	26%	25%	15%	24%
3		18%	6%	18%	27%	22%	10%	7%	9%
4		16%	9%	16%	18%	17%	6%	4%	4%
5	12%	12%	17%	12%	12%	12%	7%	4%	3%
6	52%	12%	24%	12%	11%	12%	5%	8%	8%
7	16%	5%	15%	5%	7%	6%	3%	6%	6%
8	8%	2%	3%	2%	3%	2%	2%	2%	2%
9	4%	1%	2%	1%	2%	1%	1%	1%	1%
10	4%	0%	1%	0%	1%	1%	1%	0%	0%
11		0%	0%	0%	0%	0%	2%	0%	0%
12	4%	0%	0%	0%	0%	0%	0%	0%	0%
13		0%	0%	0%	0%	0%	0%	0%	0%
14									
15+									

Age	IIa	IIb	Va	Vb	VIa	VIb	XIVb	All
0								0%
1					0%			2%
2	5%		1%	5%	2%			8%
3	8%		13%	12%	6%		1%	11%
4	17%		23%	28%	17%		8%	18%
5	15%		25%	19%	20%		29%	17%
6	21%		23%	18%	29%		32%	20%
7	14%		9%	9%	17%		16%	11%
8	9%		4%	4%	5%		8%	7%
9	6%		2%	3%	2%		4%	4%
10	3%		0%	0%	1%		1%	1%
11	1%		0%	0%	1%			1%
12	1%			0%	0%			1%
13	0%			1%				0%
14	0%				0%			0%
15+	0%							0%

Table 2.3.3.2. NE Atlantic Mackerel. Percentage catch numbers-at-age by area for 2012. Zeros represent values <1% (cont)

Quarter 3

Age	IIIa	IIIb	IIIc	IIId	IVa	IVb	IVc	VIId
0								
1	1%	1%	1%	1%	1%	3%	6%	18%
2	11%	11%	15%	8%	11%	31%	40%	28%
3	19%	19%	14%	23%	17%	14%	13%	19%
4	30%	29%	19%	39%	26%	21%	16%	19%
5	20%	20%	19%	21%	20%	17%	13%	7%
6	11%	11%	17%	6%	13%	11%	10%	8%
7	4%	4%	8%	1%	6%	2%	0%	2%
8	0%	0%	1%	0%	1%	1%		
9	2%	2%	4%	0%	2%	0%		
10	1%	1%	3%	0%	1%	0%		
11	0%	0%	0%		0%	0%		
12	0%	0%	0%		0%	0%		
13	0%	0%	0%		0%			
14	0%	0%	0%		0%	0%		
15+	0%	0%	0%		0%			

Age	VIIa	VIIb	VIIc	VIIe	VIIf	VIIg	VIIh	VIIj	VIIk
0		1%	31%	23%	0%	27%	17%	29%	31%
1	30%	4%	31%	21%	46%	27%	25%	29%	31%
2	27%	12%	8%	23%	34%	7%	17%	7%	8%
3	7%	6%	4%	15%	7%	5%	11%	4%	4%
4	11%	19%	7%	11%	6%	8%	12%	7%	7%
5	4%	9%	4%	3%	2%	6%	5%	4%	4%
6	11%	26%	3%	3%	3%	6%	5%	4%	3%
7	4%	9%	6%	1%	1%	7%	4%	7%	6%
8	2%	5%	4%	0%	0%	4%	2%	5%	4%
9	1%	4%	1%			1%	0%	1%	1%
10	2%	4%	1%	0%	0%	1%	0%	1%	1%
11	0%	0%		0%	0%	0%		0%	0%
12		0%				0%		0%	0%
13		0%				0%		0%	0%
14									
15+		0%				0%		0%	0%

Table 2.3.3.2. NE Atlantic Mackerel. Percentage catch numbers-at-age by area for 2012. Zeros represent values <1% (cont)

Quarter 3

Age	VIIIa	VIIIb	VIIIc	VIIIcE	VIIIcW	VIIId	IXaCN	IXaN	IXaS
0	37%	1%	59%	1%	3%		55%	14%	63%
1	23%	89%	37%	89%	46%		14%	67%	29%
2	20%	3%	3%	3%	17%		15%	9%	6%
3	13%	1%	1%	1%	5%	3%	5%	3%	1%
4	7%	2%	0%	2%	8%	8%	4%	3%	0%
5		1%	0%	1%	7%	6%	2%	1%	0%
6		1%	0%	1%	5%	21%	2%	1%	0%
7		1%	0%	1%	4%	17%	0%	1%	0%
8		1%	0%	1%	4%	22%	0%	1%	0%
9		0%		0%		10%	0%		
10		0%		0%		2%	0%		
11		0%		0%		5%	3%		
12		0%		0%		3%			
13		0%		0%		1%			
14									
15+						2%			

Age	IIa	IIb	Va	Vb	VIa	VIb	XIVb	All
0	0%		2%		0%			2%
1	2%		0%		10%		0%	2%
2	6%	2%	3%	1%	13%		1%	6%
3	5%	3%	8%	4%	9%		8%	7%
4	14%	12%	18%	12%	18%		21%	16%
5	18%	14%	20%	28%	19%		22%	19%
6	21%	20%	25%	18%	17%		26%	21%
7	18%	24%	13%	15%	9%		14%	15%
8	9%	14%	5%	9%	3%		4%	7%
9	4%	6%	3%	6%	1%		3%	3%
10	1%	2%	1%	3%	1%		1%	1%
11	1%	1%	0%	1%	0%		0%	1%
12	0%	0%	0%	1%	0%		0%	0%
13	0%	0%	0%	1%	0%		0%	0%
14	0%	0%	0%	0%	0%		0%	0%
15+	0%	0%		0%	0%			0%

Table 2.3.3.2. NE Atlantic Mackerel. Percentage catch numbers-at-age by area for 2012. Zeros represent values <1% (cont)

Quarter 4

Age	IIIa	IIIb	IIIc	IIId	IVa	IVb	IVc	VIId
0	0%				0%	0%		
1	3%		1%		4%	2%	30%	30%
2	11%		9%		11%	12%	24%	24%
3	23%		28%		11%	14%	29%	29%
4	35%		41%		22%	26%	9%	9%
5	15%		16%		18%	18%	3%	3%
6	7%		3%		17%	15%	3%	3%
7	3%		1%		9%	8%	0%	0%
8	1%		0%		4%	3%	1%	1%
9	1%				2%	1%	1%	1%
10	0%				1%	0%		
11	0%				0%	0%		
12	0%				0%	0%		
13	0%				0%	0%		
14	0%				0%	0%		
15+	0%				0%	0%		

Age	VIIa	VIIb	VIIc	VIIe	VIIf	VIIg	VIIh	VIIj	VIIk
0	0%	12%	28%	37%	3%	29%	36%	29%	28%
1	5%	27%	58%	23%	44%	57%	24%	56%	58%
2	12%	11%	8%	20%	33%	8%	20%	8%	8%
3	4%	5%	3%	13%	7%	4%	13%	4%	3%
4	11%	12%	1%	7%	6%	1%	7%	1%	1%
5	15%	5%	1%		2%	1%	0%	0%	1%
6	20%	16%	1%		2%	1%	0%	0%	1%
7	16%	5%	0%		1%	0%	0%	0%	0%
8	9%	2%	0%		0%	0%	0%	0%	0%
9	4%	2%					0%		
10	1%	3%			0%				
11	0%	0%			0%				
12	0%								
13	0%								
14	0%								
15+	0%								

Table 2.3.3.2. NE Atlantic Mackerel. Percentage catch numbers-at-age by area for 2012. Zeros represent values <1% (cont)

Quarter 4

Age	VIIIa	VIIIb	VIIIc	VIIIcE	VIIIcW	VIIId	IXaCN	IXaN	IXaS
0	37%	0%	47%	0%	4%	3%	88%	31%	61%
1	23%	50%	44%	50%	51%	51%	3%	37%	31%
2	20%	18%	7%	18%	17%	17%	3%	7%	6%
3	13%	10%	1%	10%	4%	6%	1%	4%	1%
4	7%	9%	1%	9%	7%	8%	3%	7%	0%
5		4%	0%	4%	6%	5%	1%	4%	0%
6		3%	0%	3%	4%	3%	1%	3%	0%
7		4%	0%	4%	4%	4%	0%	3%	0%
8		3%	0%	3%	4%	3%	0%	3%	0%
9		0%		0%		0%	0%		
10		0%		0%		0%	0%		
11		0%		0%			0%		
12		0%		0%					
13		0%		0%					
14									
15+									

Age	IIa	IIb	Va	Vb	VIa	VIb	XIVb	All
0	0%	0%	2%	0%		28%		1%
1	4%	5%	0%		3%	58%		4%
2	14%	12%	3%	2%	13%	8%		11%
3	5%	5%	8%	4%	8%	3%		11%
4	10%	11%	18%	9%	20%	1%		20%
5	15%	15%	20%	16%	13%	1%		17%
6	14%	20%	25%	18%	24%	1%		17%
7	13%	16%	13%	16%	8%	0%		9%
8	10%	9%	5%	13%	4%	0%		4%
9	7%	5%	3%	10%	3%			2%
10	3%	2%	1%	5%	4%			1%
11	3%	1%	0%	4%	0%			0%
12	1%	0%	0%	2%	0%			0%
13	0%	0%	0%	0%				0%
14	0%	0%	0%	0%	0%			0%
15+	0%	0%						0%

Table 2.3.4.1. NEA Mackerel (Southern component). Effort data by fleets.

	TRAWL		HOOK (HAND-LINE)	
	AVILES (VIIIc East) (Days * 100 CV)	A CORUÑA (VIIIc West) (Days * 100 CV)	SANTANDER (VIIIc East) (Nº fishing trips)	SANTOÑA (VIIIc East) (Nº fishing trips)
	Annual	Annual	Feb. -May	Feb. -May
1983	12568	51017	-	-
1984	10815	48655	-	-
1985	9856	45358	-	-
1986	10845	39829	-	-
1987	8309	34658	-	-
1988	9047	41498	-	-
1989	8063	44401	-	605
1990	8492	44411	322	509
1991	7677	40435	209	724
1992	12693	38896	70	698
1993	7635	44479	151	1216
1994	9620	39602	130	1926
1995	6146	41476	217	1696
1996	4525	35709	560	2007
1997	4699	35191	736	2095
1998	5929	35191	754	3022
1999	6829	30131	739	2602
2000	4453	30073	719	1709
2001	2385	29923	700	2479
2002	2748	21823	1282	2672
2003	2526	12328	265	759
2004	-	19198	626	2151
2005	-	20663	553	1504
2006	-	12866	845	1933
2007	-	21202	1031	1895
2008	-	20212	1143	1350
2009	-	21112	839	1780
2010	-	13744	533	846
2011	-	11532	796	755
2012	3168	11887	893	697

(-) Not available

Table 2.3.4.2. NEA mackerel (Southern component). CPUE index in Spanish commercial fleets.

	TRAWL		HOOK (HAND-LINE)	
	AVILES (VIIIc East) (Kg / 100 CV)	A CORUÑA (VIIIc West) (Kg / 100 CV)	SANTANDER (VIIIc East) (Kg/Nº fish. trips)	SANTOÑA (VIIIc East) (Kg/Nº fish. trips)
	Annual	Annual	Feb. -May	Feb. -May
1983	14	23	-	-
1984	24	27	-	-
1985	18	25	-	-
1986	41	23	-	-
1987	13	24	-	-
1988	16	33	-	-
1989	19	29	-	1427
1990	83	39	740	1924
1991	68	36	633	1394
1992	35	13	906	856
1993	13	13	613	1791
1994	57	44	2388	1591
1995	95	36	3136	1988
1996	124	33	1166	1509
1997	133	39	2138	1868
1998	142	80	2362	2128
1999	136	44	2438	2085
2000	312	65	1796	1880
2001	223	61	2323	2401
2002	342	58	2062	1871
2003	357	52	1868	1413
2004	-	19	2046	1313
2005	-	143	3618	2425
2006	-	442	2908	2742
2007	-	22	2676	2889
2008	-	12	1921	2832
2009	-	67	4659	3546
2010	-	67	4659	4568
2011	-	95	2033	2079
2012	77	-	1990	1896

(-) Not available

Table 2.4.1.1. NE Atlantic Mackerel. Mean length (mm) -at-age by area for 2012.

Quarters 1-4

Age	IIIa	IIIb	IIIc	IIId	IVa	IVb	IVc	VIId
0	181				181	181		
1	268	269	265	271	259	248	259	268
2	297	304	286	306	293	280	287	293
3	329	332	319	340	333	316	319	328
4	341	343	327	354	347	344	339	344
5	355	360	348	365	356	345	339	357
6	358	369	352	366	361	354	358	375
7	370	384	366	371	370	359	359	368
8	386	399	382	390	379	377	378	364
9	388	388	388	388	383	385	389	418
10	373	372	372	373	397	409	420	
11	442	431	427	454	398	386	385	
12	457	460	460	460	415	435	435	
13	443	460	460	460	404	403		
14	477	480	480	480	404	453		
15+	480	480	480	480	474	480		

Age	VIIa	VIIb	VIIc	VIIe	VIIf	VIIg	VIIh	VIIj	VIIk
0		203	203	214	214	204	214	204	204
1	237	202	193	267	236	187	208	191	193
2	280	255	291	297	280	291	293	300	291
3	308	299	307	318	306	306	312	320	308
4	323	333	334	333	308	319	323	333	323
5	340	348	352	355	311	339	341	353	346
6	350	359	360	373	312	341	343	361	350
7	353	376	388	365	323	360	361	371	362
8	375	383	398	345	339	373	370	386	376
9	392	404	412		397	397	397	393	393
10	379	405	417	325	327	412	407	400	400
11	354	407	444	325	330	415	415	412	415
12	408	420	425		416	421	421	416	421
13	425	413	435		409	426	422	409	431
14	377	425	425						
15+	442	425			425	425	425	425	425

Table 2.4.1.1. NE Atlantic Mackerel. Mean length (mm) -at-age by area for 2012 (cont)

Quarters 1-4

Age	VIIIa	VIIIb	VIIIc	VIIIcE	VIIIcW	VIIId	IXaCN	IXaN	IXaS
0	214	250	229	250	234	241	181	231	203
1	267	267	211	268	268	268	256	225	244
2	294	285	286	288	285	290	308	283	284
3	325	307	322	317	308	310	339	312	312
4	343	334	331	337	330	332	361	334	332
5	355	354	339	349	341	345	369	353	347
6	361	362	354	360	348	358	373	367	365
7	370	371	375	370	360	370	387	375	374
8	365	374	390	387	381	388	401	385	382
9	375	386	396	394	394	379	411	388	383
10	375	383	399	402	404	400	409	394	388
11		417	400	406	409	411	426	396	390
12	415	416	407	414	420	415	405	406	401
13		437	402	415	420	410	403	404	400
14									
15+						425			

Age	IIa	IIb	Va	Vb	VIa	VIb	XIVb	All
0	244		139	160	204	203		187
1	260	257	279		252	215	280	247
2	286	286	307	277	274	292	318	284
3	316	303	329	312	315	306	330	322
4	332	325	339	333	333	317	337	338
5	343	336	351	348	348	336	349	349
6	352	347	358	358	358	336	358	357
7	358	352	368	367	368	353	368	365
8	367	359	377	377	379	358	382	374
9	378	369	384	386	392	390	391	384
10	389	378	390	391	391	401	395	392
11	386	381	401	386	391	401	410	393
12	399	384	408	399	410	405	395	405
13	412	399	413	404	460		400	408
14	418	404	420	419	375		400	405
15+	452	440		440	480			442

Table 2.4.1.1. NE Atlantic Mackerel. Mean length (mm) -at-age by area for 2012 (cont)

Quarter 1

Age	IIIa	IIIb	IIIc	IIId	IVa	IVb	IVc	VIId
0								
1	263				263			
2	288				286	275	275	289
3	318				316	308	333	324
4	327				328	355	345	337
5	347				347	339		
6	352				356	355	375	375
7	367				368	351	365	365
8	383				379	365		345
9	388				389	385		
10	373				379	420		
11	460				399	385		
12	460				424	435		
13								
14	480				405			
15+	480				480			

Age	VIIa	VIIb	VIIc	VIIe	VIIf	VIIg	VIIh	VIIj	VIIk
0									
1		184	184		236	184	184	184	184
2	305	255	291	305	281	291	291	300	291
3	314	299	307	314	309	305	307	321	305
4	328	333	333	328	314	317	318	333	317
5		348	349		310	336	337	353	336
6		359	358		309	336	338	362	336
7	365	377	383	365	336	353	357	369	353
8	345	383	393	345	337	361	358	384	362
9		404	412			390	386	391	390
10		406	411		325	401	397	400	402
11		407	444		325	401	401	401	401
12		405	425			405	405	405	405
13									
14		425	425						
15+									

Table 2.4.1.1. NE Atlantic Mackerel. Mean length (mm) -at-age by area for 2012 (cont)

Quarter 1

Age	VIIIa	VIIIb	VIIIc	VIIIcE	VIIIcW	VIIId	IXaCN	IXaN	IXaS
0									
1		257	199	263	262		192	196	222
2		277	282	286	285	290	282	281	281
3		294	322	318	307	310	333	310	296
4		339	330	337	330	332	352	332	332
5	355	356	338	349	341	345	359	353	353
6	361	362	354	360	348	358	370	368	368
7	370	371	375	370	359	370	387	375	375
8	365	374	390	387	379	388	402	385	385
9	375	386	396	394	392	379	418	388	388
10	375	382	400	402	404	400	411	394	394
11		417	400	406	411		438	396	396
12	415	416	407	414	421		406	406	406
13		438	402	415	421		404	404	404
14									
15+									

Age	IIa	IIb	Va	Vb	VIa	VIb	XIVb	All
0								
1					237	184		193
2					269	291		267
3					315	305		310
4					332	317		332
5					347	336		348
6					358	336		359
7					368	353		369
8					378	361		381
9					392	390		393
10					391	401		395
11					391	401		394
12					410	405		412
13								415
14					375			377
15+								480

Table 2.4.1.1. NE Atlantic Mackerel. Mean length (mm) -at-age by area for 2012 (cont)

Quarter 2

Age	IIIa	IIIb	IIIc	IIId	IVa	IVb	IVc	VIId
0								
1	263	263	269	263	264	265	268	268
2	289	288	270	288	286	276	282	289
3	317	318	335	318	315	310	319	327
4	325	327	346	327	325	339	345	344
5	347	347	352	347	344	341	343	356
6	352	352	349	352	350	352	361	374
7	366	367	380	367	364	356	358	369
8	383	383	385	383	366	376	376	
9	388	388		388	382	386	385	
10	373	373		373	373	410	420	
11	460	460		460	460	385	385	
12	460	460		460	407	435	435	
13					385			
14	480	480		480	480	480		
15+	480	480		480	480	480		

Age	VIIa	VIIb	VIIc	VIIe	VIIf	VIIg	VIIh	VIIj	VIIk
0									
1	236	230	230	236	236	230	230	230	230
2	279	253	289	304	280	289	289	289	289
3	308	296	320	314	305	320	320	313	317
4	318	323	344	328	307	331	331	333	330
5	341	342	372	310	312	346	346	353	349
6	347	356	369	309	313	351	351	358	356
7	357	370	395	365	324	365	365	378	363
8	370	381	403	345	349	379	379	388	378
9	393	399	413		397	399	398	396	393
10	364	413	421	325	329	415	415	398	401
11	355	412	444	325	335	416	415	412	416
12	407	421	425		416	421	421	416	421
13		435	435		409	430	422	409	435
14	375	425							
15+					425	425	425	425	

Table 2.4.1.1. NE Atlantic Mackerel. Mean length (mm) -at-age by area for 2012 (cont)

Quarter 2

Age	VIIIa	VIIIb	VIIIc	VIIIcE	VIIIcW	VIIId	IXaCN	IXaN	IXaS
0							180		
1		262	233	262	262	262	223	201	225
2		286	279	286	287	287	295	277	277
3		302	317	302	313	307	333	309	307
4		321	344	321	326	324	354	328	328
5	355	339	351	339	339	339	365	345	345
6	361	349	358	349	352	350	370	365	365
7	370	362	362	362	366	364	383	373	373
8	365	383	376	383	391	387	397	382	382
9	375	396	389	396	400	398	408	383	383
10	375	402	391	402	405	403	408	387	388
11		411	403	411	406	409	433	390	390
12	415	412	415	412	412	412	401	401	401
13		412	409	412	410	411	400	400	400
14									
15+									

Age	IIa	IIb	Va	Vb	VIa	VIb	XIVb	All
0								180
1					252			240
2	278		334	271	271			283
3	309		328	309	312		350	317
4	326		337	325	333		348	331
5	339		352	337	348		352	346
6	349		354	347	360		356	353
7	359		364	359	369		368	365
8	371		377	358	381		372	376
9	379		384	368	393		377	383
10	387		360	360	396		380	389
11	395		390	390	395			402
12	397			390	417			407
13	380			385				394
14	428				375			429
15+	475							431

Table 2.4.1.1. NE Atlantic Mackerel. Mean length (mm) -at-age by area for 2012 (cont)

Quarter 3

Age	IIIa	IIIb	IIIc	IIId	IVa	IVb	IVc	VIId
0								
1	276	273	253	288	272	243	247	268
2	304	307	287	321	298	287	287	293
3	336	333	317	345	332	321	310	325
4	349	345	325	360	345	344	335	344
5	362	361	347	372	357	346	337	356
6	366	372	352	385	360	356	354	374
7	376	387	366	394	370	370	370	370
8	393	403	382	414	384	382		
9	388	388	388	388	388	384		
10	372	372	372	372	373	408		
11	427	427	427	427	414	399		
12	460	460	460	460	438	422		
13	460	460	460	460	453			
14	480	480	480	480	475	415		
15+	480	480	480	480	480			

Age	VIIa	VIIb	VIIc	VIIe	VIIf	VIIg	VIIh	VIIj	VIIk
0		204	204	214	214	204	204	204	204
1	237	252	251	267	236	251	256	251	251
2	280	283	311	293	280	312	298	311	311
3	308	312	333	325	306	334	327	333	333
4	326	336	364	343	307	361	350	362	364
5	339	350	366	355	312	365	360	366	366
6	352	359	367	374	311	367	372	364	366
7	348	360	366	369	318	370	367	369	367
8	379	388	364	325	325	370	364	371	366
9	392	393	385			392	385	391	387
10	383	391	385	325	325	387	385	387	386
11	353	416		325	325	412		412	412
12		416				416		416	416
13		409				409		409	409
14									
15+		425				425		425	425

Table 2.4.1.1. NE Atlantic Mackerel. Mean length (mm) -at-age by area for 2012 (cont)

Quarter 3

Age	VIIIa	VIIIb	VIIIc	VIIIcE	VIIIcW	VIIId	IXaCN	IXaN	IXaS
0	214	249	229	249	234		180	234	203
1	267	263	248	263	270		278	258	254
2	294	292	294	292	296		323	294	292
3	325	343	325	343	329	309	342	333	325
4	343	356	341	356	365	338	364	351	345
5		360	365	360	369	359	379	362	362
6		356	364	356	368	357	375	365	365
7		363	384	363	376	385	385	380	380
8		368	393	368	378	389	395	384	384
9		403		403		397	405		
10		416		416		398	405		
11		420		420		412	425		
12		441		441		416			
13		443		443		409			
14									
15+						425			

Age	IIa	IIb	Va	Vb	VIa	VIb	XIVb	All
0	245		139		204			184
1	260		279		267		280	261
2	286	287	305	287	290		318	291
3	317	302	329	315	334		330	324
4	333	324	339	342	347		337	337
5	343	335	351	352	357		349	347
6	352	346	359	363	362		358	355
7	358	351	369	370	374		368	361
8	366	359	377	382	386		383	369
9	378	368	384	390	388		392	381
10	388	377	391	391	402		396	388
11	386	380	402	385	400		410	390
12	401	382	408	402	423		395	403
13	415	398	413	415	460		400	415
14	415	403	420	420	431		400	417
15+	442	440		440	480			456

Table 2.4.1.1. NE Atlantic Mackerel. Mean length (mm) -at-age by area for 2012 (cont)

Quarter 4

Age	IIIa	IIIb	IIIc	IIId	IVa	IVb	IVc	VIId
0	181				181	181		
1	261		271		258	254	267	267
2	310		330		293	296	318	318
3	342		345		333	336	338	338
4	358		362		347	351	363	363
5	371		379		356	357	368	368
6	372		397		361	361	386	386
7	375		407		370	370	380	380
8	374		410		379	380	404	404
9	378				382	383	418	418
10	401				403	405		
11	393				397	399		
12	411				414	419		
13	403				403	403		
14	397				399	402		
15+	470				470	470		

Age	VIIa	VIIb	VIIc	VIIe	VIIf	VIIg	VIIh	VIIj	VIIk
0		203	203	214	214	203	214	204	203
1	257	262	263	267	238	263	267	263	263
2	283	289	303	294	280	303	295	302	303
3	314	312	314	325	308	315	326	316	314
4	334	336	342	343	309	343	344	343	342
5	345	349	347		310	347	364	347	347
6	353	359	347		309	347	378	347	347
7	362	357	349		317	349	365	349	349
8	369	385	350		325	350	381	350	350
9	383	392					418		
10	393	391			325				
11	423	420			325				
12	417								
13	425								
14	423								
15+	442								

Table 2.4.1.1. NE Atlantic Mackerel. Mean length (mm) -at-age by area for 2012 (cont)

Quarter 4

Age	VIIIa	VIIIb	VIIIc	VIIIcE	VIIIcW	VIIId	IXaCN	IXaN	IXaS
0	214	255	224	255	234	241	182	225	206
1	267	274	257	274	270	271	293	255	254
2	294	317	292	317	293	300	314	311	290
3	325	334	325	334	324	327	347	339	324
4	343	348	339	348	366	360	364	358	345
5		357	373	357	371	367	378	364	364
6		353	386	353	371	366	374	363	363
7		363	380	363	378	374	385	369	369
8		360	386	360	381	374	395	377	377
9		390		390		390	405		
10		398		398		398	405		
11		406		406		406	415		
12		425		425		425			
13		425		425		425			
14									
15+									

Age	IIa	IIb	Va	Vb	VIa	VIb	XIVb	All
0			139	160		203		194
1	257	257	279		255	263		259
2	287	284	305	298	287	303		292
3	305	313	329	326	321	314		332
4	334	334	339	340	340	342		347
5	345	345	351	344	354	347		355
6	356	354	359	355	360	347		360
7	363	362	369	362	362	349		369
8	371	369	377	367	389	350		378
9	386	383	384	382	392			384
10	400	394	391	391	392			400
11	384	419	402	387	420			391
12	392	414	408	386	422			404
13	425	425	413	380				403
14	423	423	420	410	415			399
15+	442	442						469

Table 2.4.1.2. NE Atlantic Mackerel. Percentage length composition in catches by country and fleet, 2012. Zeros represent values <1%.

Len (cm)	DE VIa Q1	DE VIIbj Q1	DK All Q3-4	FO All Q2-4	IE All Q1-4	RU All Q2-3	IC All Q2-4	NO IVa Q2-4	UKS All Q1-4
12							0		
13							0		
14							0		
15							0		
16	0			0			0	0	
17	0							0	
18	0								
19	0								
20	0								
21	0				0			0	
22	0	0						0	
23	2	0	0	0	0			0	
24	4	0		0				1	0
25	4	0	0	0	0	0	0	3	0
26	3	0	0	0	0	0	0	4	0
27	2	0	0	0	0	0	0	4	0
28	2	1	0	1	0	0	0	4	0
29	3	2	0	2	2	1	0	3	0
30	4	3	0	3	2	2	1	4	2
31	7	6	0	4	3	3	2	4	3
32	10	10	2	7	5	6	6	8	7
33	12	14	6	10	10	12	11	9	12
34	15	18	13	15	15	19	16	13	18
35	14	17	19	17	20	22	19	15	20
36	8	10	24	14	18	17	16	11	15
37	5	7	17	11	10	9	11	7	9
38	3	5	8	5	6	4	7	4	5
39	1	3	4	4	3	2	4	3	3
40	0	2	2	3	2	0	3	1	2
41	0	0	1	0	0	0	1	0	0
42	0	0	0	0	0	0	0	0	0
43	0	0	0	0	0	0	0	0	0
44		0			0	0	0		0
45	0					0			
46			0					0	
47								0	
48								0	

Table 2.4.1.2. NE Atlantic Mackerel. Percentage length composition in catches by country and fleet, 2012. Zeros represent values <1% (cont)

Len (cm)	UKE HL VIIf Q1	UKE HL VIIf Q3	ES Trawl Q1-4	ES PS Q1	ES PS Q3	ES Art Q1-4	PT Q2	PT Q4
12								
13								
14								
15								
16								4
17			0					18
18			0					65
19			0					1
20			0					0
21	0	0	0	0			0	0
22	0	18	0		3			
23	0	18	0	0	15		0	
24	2	3	0	0	11		0	
25	9	3	1	0	29		8	
26	8	10	4	0	23		34	0
27	7	13	8	0	10		16	0
28	8	10	16	0	0	0	2	1
29	11	6	15	0	0	0	0	1
30	14	5	5	0	0	0	4	0
31	14	5	7	1	1	0	5	0
32	10	5	5	3	2	2	4	0
33	7	2	11	8	1	7	5	0
34	4	0	7	14	0	15	6	0
35	2	0	5	18	0	21	4	1
36	0	0	4	18	0	21	4	2
37	0	0	4	13	0	14	2	2
38	0	0	1	9	0	8	1	0
39	0	0	1	7	0	5	0	0
40	0		0	5	0	3	0	0
41	0		0	2		1	0	0
42			0	0		0	0	
43			0	0		0	0	
44			0	0		0	0	
45				0		0	0	
46							0	
47							0	
48							0	

Table 2.4.2.1. NE Atlantic Mackerel. Mean weight (g) -at-age by area for 2012.

Quarters 1-4

Age	IIIa	IIIb	IIIc	IIId	IVa	IVb	IVc	VIId
0	52				52	52		
1	140	144	133	145	137	126	138	147
2	208	233	176	238	208	175	190	195
3	306	312	264	341	316	262	260	276
4	355	361	307	396	365	354	330	336
5	404	419	377	436	398	347	323	361
6	411	454	386	442	418	375	382	451
7	448	492	436	450	454	378	373	424
8	509	566	498	525	497	418	411	401
9	525	525	525	525	516	422	413	611
10	486	485	485	485	571	506	505	
11	590	592	592	590	576	414	408	
12	612	610	610	610	666	607	605	
13	601	620	620	620	557	557		
14	624	637	640	623	546	606		
15+	652	665	670	644	681	642		

Age	VIIa	VIIb	VIIc	VIIe	VIIf	VIIg	VIIh	VIIj	VIIk
0	60	63	63	66	66	63	66	63	63
1	112	68	57	143	112	50	74	54	57
2	186	100	180	207	186	179	190	199	181
3	245	181	214	253	240	208	233	240	212
4	290	292	289	300	246	235	253	271	244
5	331	326	341	352	254	283	288	330	303
6	374	368	365	446	255	288	296	357	319
7	381	434	459	398	280	338	348	385	350
8	466	459	493	322	316	377	374	430	399
9	534	549	559		435	452	454	457	442
10	474	559	602	287	292	511	502	489	490
11	386	560	729	287	300	514	514	511	516
12	581	535	620		528	537	537	528	538
13	678	521	592		510	563	550	510	581
14	441	651	651						
15+	738	518			518	518	518	518	518

Table 2.4.2.1. NE Atlantic Mackerel. Mean weight (g) -at-age by area for 2012 (cont)

Quarters 1-4

Age	VIIIa	VIIIb	VIIIc	VIIIcE	VIIIcW	VIIId	IXaCN	IXaN	IXaS
0	66	121	92	121	99	108	33	94	63
1	143	148	70	150	146	147	136	90	112
2	204	173	172	173	165	180	237	165	174
3	285	219	239	228	208	219	323	219	230
4	334	279	258	273	258	279	414	272	271
5	286	302	278	304	284	316	423	318	305
6	343	344	317	333	302	358	455	356	351
7	354	363	377	362	336	398	460	379	378
8	340	374	425	415	402	467	507	411	409
9	381	417	446	439	440	433	611	419	404
10	356	387	457	466	473	501	587	438	417
11		522	458	480	492	507	789	444	424
12	495	501	484	509	531	525	477	481	464
13		603	467	515	532	508	468	471	459
14									
15+						518			

Age	IIa	IIb	Va	Vb	VIa	VIb	XIVb	All
0	180	60	205	40	64	63		87
1	146	140	216		120	85	179	123
2	203	220	267	178	153	185	326	185
3	298	279	327	255	243	210	356	284
4	346	335	364	315	292	233	378	340
5	381	369	402	382	337	277	411	374
6	413	408	429	407	372	277	442	401
7	433	425	462	448	407	320	487	431
8	463	451	494	497	452	345	555	468
9	498	475	515	527	508	427	577	502
10	543	508	543	569	505	466	629	537
11	535	537	545	544	507	466	663	538
12	574	500	613	592	587	479	555	584
13	609	575	636	587	620		583	579
14	649	660	650	706	433		570	578
15+	731	806		813	670			602

Table 2.4.2.1. NE Atlantic Mackerel. Mean weight (g) -at-age by area for 2012 (cont)

Quarter 1

Age	IIIa	IIIb	IIIc	IIId	IVa	IVb	IVc	VIId
0								
1	124				123			
2	181				177	160	139	175
3	271				262	235	286	262
4	307				297	318	344	315
5	373				353	309		
6	381				375	373	433	433
7	436				416	351	405	401
8	496				454	373		322
9	525				515	390		
10	485				493	505		
11	590				517	408		
12	610				608	605		
13								
14	620				486			
15+	640				640			

Age	VIIa	VIIb	VIIc	VIIe	VIIf	VIIg	VIIh	VIIj	VIIk
0									
1		46	46		111	46	46	46	46
2	218	100	179	218	188	179	181	198	179
3	237	181	212	237	238	206	211	242	206
4	282	292	289	282	257	231	236	272	231
5		326	337		251	274	278	330	274
6		368	366		250	275	281	362	275
7	396	434	453	396	319	318	340	385	318
8	322	459	482	322	307	341	345	439	342
9		549	565			427	420	474	428
10		560	580		287	466	481	496	474
11		560	730		287	466	466	466	466
12		479	623			479	479	479	479
13									
14		651	651						
15+									

Table 2.4.2.1. NE Atlantic Mackerel. Mean weight (g) -at-age by area for 2012 (cont)

Quarter 1

Age	VIIIa	VIIIb	VIIIc	VIIIcE	VIIIcW	VIIId	IXaCN	IXaN	IXaS
0									
1		124	56	129	127		42	53	77
2		155	160	166	165	180	151	158	158
3		185	238	229	206	220	265	212	184
4		281	257	274	257	279	320	260	260
5	286	302	276	304	282	316	340	314	314
6	343	345	316	333	300	358	374	355	355
7	354	363	379	362	331	398	438	378	378
8	340	373	425	415	390	467	497	409	409
9	381	415	447	439	433	433	563	420	420
10	356	385	458	466	472	501	535	439	439
11		521	458	480	498		660	445	445
12	495	500	483	508	537		481	481	481
13		604	467	514	537		472	472	472
14									
15+									

Age	IIa	IIb	Va	Vb	VIa	VIb	XIVb	All
0								
1					84	46		52
2					136	179		126
3					239	206		216
4					286	231		282
5					334	274		328
6					369	275		362
7					406	318		397
8					447	341		440
9					503	427		485
10					500	466		493
11					503	466		503
12					587	479		555
13								514
14					433			442
15+								640

Table 2.4.2.1. NE Atlantic Mackerel. Mean weight (g) -at-age by area for 2012 (cont)

Quarter 2

Age	IIIa	IIIb	IIIc	IIId	IVa	IVb	IVc	VIId
0								
1	123	124	140	124	125	130	148	148
2	183	181	146	181	179	163	173	184
3	271	271	265	271	257	244	255	269
4	307	307	318	307	285	324	333	336
5	375	373	340	373	347	327	322	354
6	386	381	320	381	360	361	390	446
7	435	436	452	436	402	359	364	428
8	490	496	565	496	383	404	400	
9	525	525		525	476	413	390	
10	485	485		485	485	500	505	
11	590	590		590	590	409	408	
12	610	610		610	463	605	605	
13					404			
14	620	620		620	620	620		
15+	640	640		640	640	640		

Age	VIIa	VIIb	VIIc	VIIe	VIIf	VIIg	VIIh	VIIj	VIIk
0									
1	111	89	89	111	111	89	89	89	89
2	185	96	175	216	186	175	175	177	175
3	240	172	238	237	239	238	238	221	230
4	263	266	292	282	243	264	264	266	259
5	321	280	366	251	254	301	301	324	313
6	344	345	364	250	256	313	313	334	336
7	378	388	467	395	281	352	352	384	353
8	423	436	502	322	336	393	394	419	404
9	507	500	555		435	456	455	434	442
10	411	563	616	287	296	516	515	466	490
11	386	534	729	287	313	517	517	511	517
12	574	539	619		528	538	538	528	539
13		592	592		510	577	550	510	592
14	433	651							
15+					518	518	518	518	

Table 2.4.2.1. NE Atlantic Mackerel. Mean weight (g) -at-age by area for 2012 (cont)

Quarter 2

Age	VIIIa	VIIIb	VIIIc	VIIIcE	VIIIcW	VIIId	IXaCN	IXaN	IXaS
0							32		
1		127	89	127	127	127	87	57	80
2		166	154	166	168	167	194	152	151
3		196	227	196	217	207	286	210	205
4		236	290	236	248	242	352	252	251
5	286	279	309	279	278	278	394	293	294
6	343	303	328	303	311	307	402	349	349
7	354	340	339	340	352	346	448	372	372
8	340	404	382	404	427	416	512	398	398
9	381	444	422	444	458	451	561	403	403
10	356	465	430	465	477	471	571	417	417
11		500	471	500	481	490	706	423	423
12	495	502	513	502	501	501	463	463	463
13		502	492	502	494	498	459	459	459
14									
15+									

Age	IIa	IIb	Va	Vb	VIa	VIb	XIVb	All
0								32
1					115			106
2	195		310	155	140			179
3	273		282	223	225		431	259
4	310		319	255	285		414	299
5	349		357	283	333		435	340
6	372		371	305	372		441	359
7	402		400	334	405		464	391
8	437		442	335	450		485	425
9	460		458	358	497		487	446
10	484		352	352	509		464	477
11	512		468	468	532			512
12	498			417	619			513
13	435			404				453
14	618				433			617
15+	725							542

Table 2.4.2.1. NE Atlantic Mackerel. Mean weight (g) -at-age by area for 2012 (cont)

Quarter 3

Age	IIIa	IIIb	IIIc	IIId	IVa	IVb	IVc	VIId
0								
1	167	160	113	195	157	124	125	148
2	231	242	177	288	212	196	192	198
3	324	316	259	360	312	283	240	264
4	379	366	301	415	366	362	323	334
5	426	425	375	462	411	363	319	354
6	444	468	386	523	418	386	371	451
7	468	505	435	526	450	456	436	436
8	542	586	491	635	511	507		
9	525	525	525	525	525	516		
10	485	485	485	485	490	627		
11	592	592	592	592	586	587		
12	610	610	610	610	638	704		
13	620	620	620	620	631			
14	640	640	640	640	644	663		
15+	670	670	670	670	670			

Age	VIIa	VIIb	VIIc	VIIe	VIIf	VIIg	VIIh	VIIj	VIIk
0		64	64	66	66	64	64	64	64
1	112	124	123	144	112	123	131	123	123
2	186	186	244	201	186	244	210	244	244
3	248	263	304	275	240	298	273	300	303
4	305	338	403	333	246	383	356	392	401
5	342	374	410	353	255	389	378	401	408
6	391	411	412	448	257	390	439	383	403
7	382	415	408	431	270	413	414	407	408
8	499	506	401	287	287	408	401	406	402
9	546	533	480			476	480	459	472
10	490	517	480	287	287	478	480	476	479
11	385	571		287	287	511		511	511
12		528				528		528	528
13		510				510		510	510
14									
15+		518				518		518	518

Table 2.4.2.1. NE Atlantic Mackerel. Mean weight (g) -at-age by area for 2012 (cont)

Quarter 3

Age	VIIIa	VIIIb	VIIIc	VIIIcE	VIIIcW	VIIId	IXaCN	IXaN	IXaS
0	66	120	92	120	99		32	98	63
1	143	144	119	144	156		169	135	128
2	204	198	204	198	208		282	204	199
3	285	331	279	331	290	215	351	302	279
4	334	375	325	375	405	275	443	357	339
5		386	404	386	420	335	513	394	394
6		375	403	375	416	324	495	404	404
7		399	476	399	445	396	544	460	460
8		415	511	415	454	419	598	475	475
9		557		557		435	658		
10		612		612		456	658		
11		630		630		511	798		
12		738		738		528			
13		751		751		510			
14									
15+						518			

Age	IIa	IIb	Va	Vb	VIa	VIb	XIVb	All
0	180		205		64			106
1	146		216		138		179	145
2	203	229	264	218	190		326	213
3	303	279	338	294	305		356	315
4	350	334	373	378	350		378	360
5	383	368	411	412	385		410	395
6	415	407	437	454	405		442	424
7	434	424	468	481	456		488	445
8	465	450	500	532	514		559	476
9	499	474	520	570	522		582	511
10	546	504	549	573	579		638	545
11	540	535	555	546	587		663	554
12	588	489	613	624	702		555	598
13	628	569	636	687	620		583	640
14	656	659	650	713	658		570	655
15+	734	813		813	670			709

Table 2.4.2.1. NE Atlantic Mackerel. Mean weight (g) -at-age by area for 2012 (cont)

Quarter 4

Age	IIIa	IIIb	IIIc	IIId	IVa	IVb	IVc	VIId
0	52				52	52		
1	146		167		136	135	146	146
2	255		305		208	218	261	261
3	347		355		318	328	322	322
4	401		410		365	379	392	392
5	453		479		396	404	436	436
6	472		569		418	417	493	493
7	491		640		454	457	470	470
8	494		662		497	501	568	568
9	510				514	515	611	611
10	586				593	614		
11	562				576	585		
12	654				669	691		
13	557				557	557		
14	527				539	563		
15+	690				690	690		

Age	VIIa	VIIb	VIIc	VIIe	VIIf	VIIg	VIIh	VIIj	VIIk
0	60	63	63	66	66	63	66	63	63
1	139	142	143	143	113	143	143	143	143
2	188	197	225	204	187	223	206	222	225
3	291	259	250	285	247	254	287	257	250
4	349	338	331	334	251	331	336	332	331
5	387	374	345		251	345	418	345	345
6	416	413	345		250	345	464	345	345
7	438	415	350		268	350	413	350	350
8	470	520	355		287	355	474	355	355
9	511	546					611		
10	569	518			287				
11	656	625			287				
12	673								
13	678								
14	680								
15+	738								

Table 2.4.2.1. NE Atlantic Mackerel. Mean weight (g) -at-age by area for 2012 (cont)

Quarter 4

Age	VIIIa	VIIIb	VIIIc	VIIIcE	VIIIcW	VIIId	IXaCN	IXaN	IXaS
0	66	130	85	130	99	108	33	87	65
1	143	162	133	162	155	158	199	129	127
2	204	258	198	258	201	219	257	244	195
3	285	306	279	306	277	286	369	320	277
4	334	348	319	348	408	389	444	379	339
5		376	435	376	428	412	511	402	402
6		365	483	365	427	407	492	397	397
7		399	459	399	454	437	544	420	420
8		389	483	389	464	440	599	449	449
9		498		498		498	658		
10		532		532		532	658		
11		570		570		570	722		
12		655		655		655			
13		658		658		658			
14									
15+									

Age	IIa	IIb	Va	Vb	VIa	VIb	XIVb	All
0	60	60	205	40		63		48
1	144	140	216		127	143		138
2	205	190	264	249	191	225		207
3	257	286	338	322	281	250		314
4	342	348	373	366	341	331		364
5	376	385	411	379	378	345		394
6	418	416	437	415	412	345		418
7	440	439	468	438	427	350		452
8	473	470	500	459	530	355		494
9	532	513	520	516	545			520
10	599	573	549	551	521			582
11	528	643	555	535	625			553
12	560	661	613	529	704			618
13	678	678	636	504				558
14	680	680	650	629	663			545
15+	738	738						691

Table 2.5.1: Participating countries, vessels, areas assigned, dates and sampling periods of the 2013 mackerel and horse mackerel egg surveys.

Country	Vessel	Areas	Dates	Period
Portugal	D. Carlos I	Cadiz, Portugal & Galicia	10th Feb – 19th Feb	1
Spain (IEO)	Angeles Alvarino	Cantabrian Sea & Biscay	7th Mar – 29th Mar	2
		Biscay & Cantabrian Sea	1st Apr – 22nd Apr	3
Germany	W. Herwig III	West Ireland & Celtic Sea	27th Mar – 22nd Apr	3
Netherlands	Tridens	Celtic Sea	7th May – 22nd May	4
		Celtic Sea & Biscay	3rd June – 18th June	5
Spain (AZTI)	R/V ANGELES ALVARIÑO	Biscay	22nd Mar – 6th Apr	3
	Margalef	Biscay & Cantabrian Sea	13th May – 4th June	4
Norway	MS EROS	West Ireland & West of Scotland	14th May – 5th June	4
Ireland	Celtic Explorer	Celtic Sea & Biscay	18th Feb – 10th Mar	2
		Celtic Sea, West Ireland & West of Scotland	15th July – 31st July	6
Scotland	Scotia (IBTSQ1)	West of Scotland	20th Feb – 2nd Mar	2
	ALTAIRE	NW Ireland & West of Scotland	14th Mar – 27th Mar	2
	Scotia	West of Ireland & West of Scotland	19th Apr – 7th May	3
	Christina S	West of Ireland & West of Scotland	4th June– 24th June	5
Faroe Islands	Magnus Heinason	Faroes & Shetland	23rd May – 2nd June	4
Iceland	Bjarni Saemundsson	Faroes & Shetland	11th June– 26th June	5

Table 2.5.3.2.1. Swept area estimates of NEA mackerel biomass in the different Exclusive Economic Zones (EEZs) according to the international coordinated ecosystem (IESSNS) survey in July-August 2013. NEA mackerel in the Svalbard zone contributed with 1.6% of the total estimated biomass.

	Area (1000 km^2)	Biomass (1000 tonnes)	Biomass (%)
Total	3254	8847	100
Faroese EEZ	374	1525	17.2
Icelandic EEZ	614	1525	17.2
Norwegian EEZ	988	3405	38.5
Jan Mayen EEZ	229	584	6.6
EU EEZ	401	324	3.7
Greenlandic EEZ	162	504	5.7
International waters, north	392	919	10.4
International waters, west	93	62	0.7

Table 2.5.3.3.1. Biomass, abundance, mean length and mean weight at age of mackerel from the Spanish spring acoustics surveys (PELACUS 04) from 2001 to 2013.

	2001				2002				2003			
AGE	Number (millions)	L (cm)	W (g)	Biomass t ('000)	Number (millions)	L (cm)	W (g)	Biomass t ('000)	Number (millions)	L (cm)	W (g)	Biomass t ('000)
1	29.0	25.9	126.2	3.7	621.4	23.3	80.5	50.0	5678.6	23.1	81.6	463.2
2	47.6	31.0	213.7	10.2	94.8	32.0	221.9	21.0	324.5	28.9	165.1	53.6
3	184.3	33.7	277.3	51.1	378.1	34.3	277.1	104.8	109.0	33.5	261.3	28.5
4	386.6	36.1	340.3	131.6	706.8	35.8	317.9	224.7	229.0	35.0	299.7	68.6
5	382.1	37.5	383.0	146.4	1065.9	36.8	348.0	370.9	265.2	37.1	359.1	95.2
6	393.6	38.0	397.7	156.5	604.6	38.2	390.9	236.3	230.1	38.0	385.7	88.8
7	202.7	39.5	446.7	90.5	674.5	39.1	419.2	282.8	94.3	39.8	443.4	41.8
8	143.5	40.0	464.5	66.7	191.4	39.9	447.2	85.6	88.5	40.1	454.6	40.2
9	83.7	40.5	481.7	40.3	158.4	40.3	461.4	73.1	19.6	41.5	505.1	9.9
10	17.0	40.2	469.3	8.0	100.2	41.0	490.2	49.1	10.0	41.9	519.9	5.2
11	26.3	42.1	541.4	14.2	54.0	41.4	504.0	27.2	14.0	42.6	549.6	7.7
12	12.3	41.9	533.8	6.5	12.4	43.5	586.7	7.3	3.8	41.5	503.1	1.9
13	1.9	41.5	517.1	1.0	0.0	0.0	0.0	0.0	3.7	43.1	566.9	2.1
14	6.1	43.5	596.5	3.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15+	9.4	42.8	568.1	5.3	2.9	45.5	676.9	2.0	2.0	43.3	578.1	1.2
TOTAL	1926.2	37.3	381.9	735.6	4665.3	35.5	329.0	1534.8	7072.1	25.5	128.4	907.8
	2004				2005				2006			
1	195.2	25.0	114.6	22.4	43.4	24.8	112.1	4.6	83.7	20.8	58.5	4.9
2	952.4	28.3	164.5	156.6	106.5	29.2	181.8	19.0	9.3	29.7	177.2	1.7
3	599.3	32.8	258.1	154.7	229.1	32.3	245.4	56.1	57.3	31.9	223.1	12.8
4	227.5	37.5	377.8	86.0	259.6	36.5	349.4	92.4	230.7	33.5	262.7	60.6
5	425.6	38.1	395.5	168.3	82.6	38.3	403.4	34.2	104.7	36.7	345.0	36.1
6	336.7	39.1	428.4	144.2	163.8	38.8	417.6	70.4	34.2	38.5	398.1	13.6
7	181.5	40.1	461.7	83.8	114.9	39.5	438.4	52.0	22.2	39.2	420.5	9.3
8	106.1	40.8	483.2	51.3	63.8	39.8	451.7	29.8	7.6	40.9	483.3	3.6
9	76.5	41.0	492.5	37.7	33.6	41.0	493.9	17.2	2.0	41.9	513.6	1.0
10	31.1	42.3	538.0	16.7	15.3	42.3	535.4	8.5	3.4	41.3	495.1	1.7
11	18.9	42.2	533.9	10.1	13.7	41.8	518.8	7.4	1.4	42.7	545.7	0.8
12	13.5	43.3	573.8	7.7	6.6	42.0	526.6	3.6	0.5	42.8	551.1	0.3
13	3.2	43.9	599.8	1.9	11.3	42.5	544.1	6.4	0.1	43.8	590.7	0.1
14	0.0	0.0	0.0	0.0	5.1	43.8	592.6	3.2	0.0	0.0	0.0	0.0
15+	5.9	46.4	710.5	4.2	7.3	43.7	594.9	4.6	0.0	44.5	621.0	0.0
TOTAL	3173.2	33.8	298.0	945.6	1156.6	35.9	346.7	409.5	557.3	32.7	263.0	146.6
	2007				2008				2009			
1	182.2	21.5	64.1	11.7	407.1	24.4	100.4	40.9	7.5	24.3	98.5	0.7
2	34.6	25.6	110.5	3.8	100.5	27.1	135.2	13.6	65.1	29.3	176.1	11.5
3	22.1	33.4	254.5	5.6	327.4	29.8	180.7	59.1	148.4	30.0	189.4	28.1
4	129.6	34.9	291.7	37.8	125.8	33.5	261.9	32.9	201.7	32.5	248.1	50.0
5	189.4	36.1	324.0	61.4	233.6	36.2	328.2	76.5	86.8	35.0	314.3	27.3
6	117.5	38.1	379.7	44.6	277.5	36.3	328.5	91.0	148.8	36.9	370.0	55.0
7	31.9	39.8	435.9	13.9	131.0	37.9	374.1	48.9	180.8	37.7	394.7	71.3
8	20.5	39.7	431.5	8.8	25.2	39.5	423.4	10.6	93.0	39.5	454.8	42.2
9	4.8	41.2	484.0	2.3	20.1	39.5	422.7	8.5	32.6	40.2	484.7	15.7
10	6.1	40.7	464.7	2.8	20.5	40.2	443.6	9.0	14.9	40.7	500.8	7.5
11	1.5	41.4	490.3	0.8	9.2	41.1	474.8	4.4	4.6	41.6	537.0	2.4
12	4.7	44.5	608.6	2.8	7.3	41.8	500.0	3.6	3.5	42.2	561.9	2.0
13	0.7	43.5	567.6	0.4	2.4	43.4	561.4	1.3	4.1	42.4	569.2	2.3
14	2.6	44.0	591.5	1.5	1.1	44.6	607.1	0.7	0.0	0.0	0.0	0.0
15+	0.7	46.5	697.9	0.5	0.4	46.5	690.3	0.3	0.0	0.0	0.0	0.0
TOTAL	748.9	32.5	265.4	198.8	1689.2	31.7	238.0	401.4	991.8	34.8	319.0	316.2

Table 2.5.3.3.1. continued.

	2010				2011				2012			
1	431.8	23.6	89.2	38.6	1936.9	22.5	77.4	149.3	698.05	22.07	74.36	51.83
2	72.7	30.6	194.8	14.2	29.7	30.5	201.3	6.0	16.7	27.71	150.62	2.5
3	189.6	31.5	214.9	40.9	63.1	32.3	239.2	15.1	11.18	33.27	265.58	2.98
4	662.7	33.6	262.3	174.1	90.6	33.7	273.6	24.7	32.34	34.63	299.04	9.69
5	873.3	35.0	296.3	258.8	154.8	35.0	308.5	47.6	60.04	35.62	325.28	19.53
6	306.6	36.8	346.3	106.1	144.1	36.1	340.6	49.0	147.09	36.58	353.17	51.84
7	388.9	38.1	385.6	149.8	57.7	38.2	406.2	23.4	121.31	37.66	386.73	46.77
8	239.2	38.2	388.3	92.8	54.2	39.5	446.9	24.1	61.9	39.43	445.95	27.53
9	113.9	39.5	427.5	48.6	31.2	39.6	451.5	14.0	32.39	40.12	470.22	15.19
10	26.4	40.8	470.2	12.4	10.3	41.0	503.5	5.2	19.11	40.54	485.42	9.26
11	16.5	40.9	475.8	7.8	4.7	41.0	503.1	2.4	8.07	40.66	489.56	3.94
12	10.3	41.4	492.4	5.0	3.1	41.8	533.3	1.6	2.78	41.94	538.24	1.49
13	7.5	41.9	509.7	3.8	2.4	41.6	527.1	1.2	1.36	42.38	555.37	0.75
14	5.3	42.4	530.5	2.8	0.0	0.0	0.0	0.0	1.36	42.38	555.37	0.75
15+	3.0	43.1	557.7	1.7	0.0	0.0	0.0	0.0	1.19	44.53	649.03	0.78
TOTAL	3347.8	34.0	286.0	957.5	2582.9	25.8	141.2	363.7	1214.88	28.46	201.91	244.81
	2013											
1	99	24.5	93.0	9								
2	653	26.5	119.1	81								
3	123	28.6	152.4	20								
4	114	34.2	267.6	31								
5	228	35.3	296.0	68								
6	235	36.2	322.3	76								
7	178	36.7	335.3	60								
8	64	37.6	361.4	23								
9	11	38.1	378.2	4								
10	8	40.0	439.4	4								
11	3	40.8	470.1	1								
12	2	41.2	490.3	1								
13												
14												
15+												
TOTAL	1718	31.2	200.2	379								

Table 2.5.3.3.2. Mackerel Abundance and Biomass by ICES sub-divisions from Spanish spring acoustic surveys (PELACUS04) from 2001 to 2013.

	ICES IXa-N		ICES VIIIc-W		VIIIc-EW		VIIIc-EE		TOTAL	
	Abund. (10^9)	Biomass (kt)	Abund. (10^9)	Biomass (kt)	Abund. (10^9)	Biomass (kt)	Abund. (10^9)	Biomass (kt)	Abund. (10^9)	Biomass (kt)
2001	0.02	7.4	0.31	120.1	1.23	489.1	0.36	119.1	1.93	735.7
2002	0.00	0.0	0.82	333.7	3.80	1191.1	0.04	10.0	4.67	1534.8
2003	4.58	376.6	1.07	184.4	0.88	202.5	0.54	144.3	7.14	907.8
2004	0.61	118.6	1.03	304.3	1.50	515.7	0.03	7.0	3.17	945.6
2005	0.16	45.6	0.23	13.0	0.60	228.6	0.16	32.3	1.06	409.5
2006	0.01	0.7	0.39	100.5	0.15	41.5	0.02	4.0	0.56	146.6
2007	0.16	11.2	0.22	77.4	0.36	108.4	0.01	1.8	0.75	198.8
2008	0.16	21.4	0.38	109.0	0.84	235.0	0.05	4.2	1.42	369.7
2009	0.06	11.8	0.04	10.1	0.57	220.2	0.33	74.1	0.99	316.2
2010	0.38	34.2	0.88	293.7	2.09	628.6	0.00	1.0	3.35	957.5
2011	1.42	109.2	0.51	39.4	0.65	212.4	0.01	2.7	2.58	363.7
2012	0.61	45.03	0.02	1.3	0.57	190.7	0.02	7.8	1.21	244.8
2013	0.00	00.00	0.46	58.0	1.06	270.9	0.19	49.7	1.72	378.6

TABLE 2.6.1 NEA Mackerel. CATCH IN NUMBER

Units : Thousands

age	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
0	10707	16997	29277	36171	62510	6077	34623	114529	33101	56682
1	34979	46267	108077	62908	282818	175220	34513	360698	411327	276229
2	51652	74544	47410	92385	249293	328732	560738	62909	393025	502365
3	194461	109015	155390	84509	374245	226560	449338	609522	64549	231814
4	650980	415015	148543	265129	176793	236116	279236	385578	328206	32814
5	0	814518	424462	164673	314261	67758	282158	250755	254172	184867
6	0	0	673317	251420	133822	186619	78877	248099	142978	173349
7	0	0	0	991632	379790	105004	172213	92655	145385	116328
8	0	0	0	0	478925	229803	73933	169605	54778	125548
9	0	0	0	0	0	236966	127975	73900	130771	41186
10	0	0	0	0	0	0	243333	102363	39920	146186
11	0	0	0	0	0	0	0	204291	56210	31639
12	0	0	0	0	0	0	0	0	104927	199615

age	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
0	11180	7333	287287	81799	49983	7403	57644	65400	24246	10007
1	213936	47914	31901	268960	58126	40126	152656	64263	140534	58459
2	432867	668909	86064	20893	424563	156670	137635	312739	209848	212521
3	472457	433744	682491	58346	38387	663378	190403	207689	410751	206421
4	184581	373262	387582	445357	76545	56680	538394	167588	208146	375451
5	26544	126533	251503	252217	364119	89003	72914	362469	156742	188623
6	138970	20175	98063	165219	208021	244570	87323	48696	254015	129145
7	112476	90151	22086	62363	126174	150588	201021	58116	42549	197888
8	89672	72031	61813	19562	42569	85863	122496	111251	49698	51077
9	88726	48668	47925	47560	13533	34795	55913	68240	85447	43415
10	27552	49252	37482	37607	32786	19658	20710	32228	33041	70839
11	91743	19745	30105	26965	22971	25747	13178	13904	16587	29743
12	156121	132040	69183	97652	81153	63146	57494	35814	27905	52986

age	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
0	43447	19354	25368	14759	37956	36012	61127	67003	36345	26034
1	83583	128144	147315	81529	119852	144390	99352	73597	102407	40315
2	156292	210319	221489	340898	168882	186481	229767	132994	142898	158943
3	356209	266677	306979	340215	333365	238426	264566	223639	275376	234186
4	266591	398240	267420	275031	279182	378881	323186	261778	390858	297206
5	306143	244285	301346	186855	177667	246781	361945	281041	295516	309937
6	156070	255472	184925	197856	96303	135059	207619	244212	241550	231804
7	113899	149932	189847	142342	119831	84378	118388	159019	175608	195250
8	138458	97746	106108	113413	55812	66504	72745	86739	106291	120241
9	51208	121400	80054	69191	59801	39450	47353	50613	52394	72205
10	36612	38794	57622	42441	25803	26735	24386	30363	31280	42529
11	40956	29067	20407	37960	18353	13950	16551	17048	18918	20546
12	68205	68217	57551	39753	30648	24974	22932	32446	34202	40706

age	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
0	70409	14409	5168	5014	58294	15374	25738	16560	22881	3165
1	222214	182121	24617	44235	69303	79398	42029	34803	47097	58502
2	69728	265153	425834	131909	165134	189765	156841	108722	135132	104936
3	366981	88950	499455	661629	156631	227859	386710	448286	300022	317555
4	349853	290227	142792	289505	468403	204001	279310	615164	733096	464654
5	262485	230568	244885	118453	194147	448612	257358	320584	610861	649155
6	236927	180479	137998	119907	96817	200620	253961	223592	284355	485692
7	151241	132355	83997	63297	73749	75312	123294	193310	142848	243680
8	118814	93165	61426	38025	33234	58619	56833	73296	102107	112531
9	79919	74779	37614	23744	18785	28301	32082	29550	45913	53410
10	43776	45793	32816	18703	13951	16451	19186	14861	21225	25213
11	21606	25691	15385	7863	8313	11796	6779	7429	6273	12372
12	40260	30887	18151	10558	10071	13548	9580	4943	8590	10780

age	2012
0	26229
1	67023
2	203538
3	215752
4	415043
5	452744
6	509420
7	322600
8	143459
9	70068
10	30432
11	11993
12	12143

TABLE 2.6.2 NEA Mackerel. WEIGHTS AT AGE IN THE CATCH

Units : Kg

year

age	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
0	0.052	0.050	0.051	0.050	0.059	0.056	0.036	0.016	0.057	0.060	0.053	0.050
1	0.135	0.145	0.136	0.148	0.137	0.136	0.135	0.137	0.131	0.132	0.131	0.168
2	0.277	0.194	0.229	0.177	0.207	0.169	0.161	0.161	0.249	0.248	0.249	0.219
3	0.341	0.285	0.261	0.259	0.263	0.275	0.250	0.243	0.285	0.287	0.285	0.276
4	0.423	0.368	0.334	0.323	0.320	0.333	0.325	0.318	0.345	0.344	0.345	0.310
5	NaN	0.448	0.392	0.348	0.346	0.352	0.345	0.348	0.378	0.377	0.378	0.386
6	NaN	NaN	0.481	0.430	0.406	0.407	0.403	0.401	0.454	0.454	0.454	0.425
7	NaN	NaN	NaN	0.488	0.443	0.446	0.421	0.416	0.498	0.499	0.496	0.435
8	NaN	NaN	NaN	NaN	0.518	0.546	0.518	0.506	0.520	0.513	0.513	0.498
9	NaN	NaN	NaN	NaN	NaN	0.537	0.536	0.513	0.542	0.543	0.541	0.545
10	NaN	NaN	NaN	NaN	NaN	NaN	0.529	0.537	0.574	0.573	0.574	0.606
11	NaN	NaN	NaN	NaN	NaN	NaN	NaN	0.522	0.590	0.576	0.574	0.608
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.580	0.584	0.582	0.614

year

age	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
0	0.031	0.055	0.039	0.076	0.055	0.049	0.085	0.068	0.051	0.061	0.046	0.072
1	0.102	0.144	0.146	0.179	0.133	0.136	0.156	0.156	0.167	0.134	0.136	0.143
2	0.184	0.262	0.245	0.223	0.259	0.237	0.233	0.253	0.239	0.240	0.255	0.234
3	0.295	0.357	0.335	0.318	0.323	0.320	0.336	0.327	0.333	0.317	0.339	0.333
4	0.326	0.418	0.423	0.399	0.388	0.377	0.379	0.394	0.397	0.376	0.390	0.390
5	0.344	0.417	0.471	0.474	0.456	0.433	0.423	0.423	0.460	0.436	0.448	0.452
6	0.431	0.436	0.444	0.512	0.524	0.456	0.467	0.469	0.495	0.483	0.512	0.501
7	0.542	0.521	0.457	0.493	0.555	0.543	0.528	0.506	0.532	0.527	0.543	0.539
8	0.480	0.555	0.543	0.498	0.555	0.592	0.552	0.554	0.555	0.548	0.590	0.577
9	0.569	0.564	0.591	0.580	0.562	0.578	0.606	0.609	0.597	0.583	0.583	0.594
10	0.628	0.629	0.552	0.634	0.613	0.581	0.606	0.630	0.651	0.595	0.627	0.606
11	0.636	0.679	0.694	0.635	0.624	0.648	0.591	0.649	0.663	0.647	0.678	0.631
12	0.663	0.710	0.688	0.718	0.697	0.739	0.713	0.708	0.669	0.679	0.713	0.672

year

age	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
0	0.058	0.076	0.065	0.062	0.063	0.069	0.052	0.081	0.086	0.067	0.042	0.093
1	0.143	0.143	0.157	0.176	0.135	0.172	0.160	0.171	0.160	0.149	0.099	0.121
2	0.226	0.230	0.227	0.235	0.227	0.224	0.256	0.271	0.267	0.270	0.196	0.218
3	0.313	0.295	0.310	0.306	0.306	0.305	0.307	0.338	0.326	0.307	0.307	0.295
4	0.377	0.359	0.354	0.361	0.363	0.376	0.367	0.387	0.402	0.366	0.357	0.369
5	0.425	0.415	0.408	0.404	0.427	0.424	0.425	0.439	0.422	0.434	0.428	0.408
6	0.484	0.453	0.452	0.452	0.463	0.474	0.460	0.477	0.488	0.440	0.480	0.453
7	0.518	0.481	0.462	0.500	0.501	0.496	0.512	0.523	0.523	0.495	0.494	0.505
8	0.551	0.524	0.518	0.536	0.534	0.540	0.537	0.572	0.557	0.539	0.543	0.529
9	0.576	0.553	0.550	0.569	0.567	0.577	0.580	0.612	0.575	0.556	0.584	0.569
10	0.596	0.577	0.573	0.586	0.586	0.603	0.601	0.631	0.598	0.582	0.625	0.575
11	0.603	0.591	0.591	0.607	0.594	0.611	0.629	0.648	0.633	0.635	0.635	0.587
12	0.670	0.636	0.631	0.687	0.644	0.666	0.665	0.715	0.686	0.657	0.690	0.668

year

age	2008	2009	2010	2011	2012
0	0.051	0.106	0.048	0.071	0.087
1	0.128	0.156	0.148	0.114	0.123
2	0.227	0.215	0.222	0.241	0.185
3	0.295	0.283	0.293	0.283	0.284
4	0.371	0.331	0.331	0.335	0.340
5	0.418	0.388	0.365	0.369	0.374
6	0.444	0.424	0.418	0.412	0.401
7	0.497	0.451	0.470	0.452	0.431
8	0.550	0.496	0.487	0.495	0.468
9	0.570	0.538	0.515	0.541	0.502
10	0.620	0.586	0.573	0.579	0.537
11	0.595	0.598	0.604	0.610	0.538
12	0.662	0.630	0.629	0.665	0.582

TABLE 2.6.3 NEA Mackerel.WEIGHTS AT AGE IN THE STOCK

Units : Kg

age \ year	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
0	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008
1	0.132	0.132	0.130	0.129	0.128	0.127	0.111	0.110	0.109	0.087	0.086	0.086
2	0.178	0.177	0.173	0.171	0.170	0.167	0.175	0.174	0.173	0.186	0.135	0.172
3	0.243	0.242	0.238	0.236	0.236	0.233	0.238	0.237	0.236	0.252	0.221	0.235
4	0.411	0.301	0.296	0.294	0.293	0.289	0.300	0.299	0.297	0.313	0.280	0.280
5	0.000	0.438	0.322	0.318	0.318	0.313	0.346	0.345	0.343	0.323	0.385	0.339
6	0.000	0.000	0.469	0.365	0.365	0.361	0.382	0.380	0.379	0.378	0.353	0.377
7	0.000	0.000	0.000	0.497	0.419	0.416	0.410	0.408	0.407	0.419	0.408	0.404
8	0.000	0.000	0.000	0.000	0.512	0.446	0.432	0.430	0.429	0.434	0.437	0.439
9	0.000	0.000	0.000	0.000	0.000	0.530	0.451	0.449	0.448	0.449	0.446	0.503
10	0.000	0.000	0.000	0.000	0.000	0.000	0.514	0.504	0.503	0.443	0.479	0.473
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.516	0.508	0.523	0.526	0.555
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.518	0.531	0.534	0.563

age \ year	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	0.081	0.085	0.077	0.078	0.072	0.076	0.074	0.075	0.078	0.078	0.079	0.081
2	0.194	0.165	0.179	0.148	0.156	0.177	0.138	0.155	0.212	0.197	0.178	0.164
3	0.253	0.293	0.267	0.240	0.237	0.244	0.222	0.230	0.259	0.268	0.237	0.267
4	0.295	0.306	0.304	0.286	0.301	0.306	0.287	0.307	0.310	0.315	0.301	0.326
5	0.324	0.341	0.356	0.374	0.329	0.352	0.339	0.357	0.362	0.360	0.361	0.398
6	0.393	0.384	0.351	0.386	0.423	0.380	0.373	0.409	0.402	0.416	0.413	0.448
7	0.436	0.430	0.416	0.411	0.445	0.429	0.414	0.432	0.424	0.454	0.466	0.491
8	0.441	0.459	0.473	0.429	0.432	0.474	0.409	0.502	0.462	0.465	0.470	0.508
9	0.479	0.468	0.443	0.482	0.455	0.457	0.437	0.541	0.487	0.484	0.483	0.546
10	0.520	0.559	0.468	0.499	0.522	0.466	0.514	0.566	0.522	0.511	0.550	0.514
11	0.510	0.579	0.497	0.470	0.589	0.510	0.523	0.566	0.552	0.585	0.608	0.619
12	0.550	0.607	0.575	0.549	0.632	0.595	0.529	0.594	0.583	0.577	0.584	0.639

age \ year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	0.076	0.076	0.077	0.081	0.074	0.078	0.078	0.074	0.059	0.074	0.076	0.064
2	0.133	0.186	0.149	0.194	0.185	0.164	0.181	0.181	0.138	0.168	0.178	0.169
3	0.251	0.228	0.223	0.242	0.235	0.241	0.239	0.273	0.246	0.238	0.228	0.225
4	0.317	0.296	0.285	0.301	0.289	0.342	0.311	0.316	0.313	0.336	0.297	0.277
5	0.366	0.361	0.342	0.353	0.350	0.390	0.364	0.371	0.355	0.381	0.345	0.308
6	0.444	0.402	0.400	0.396	0.390	0.446	0.411	0.446	0.412	0.401	0.391	0.363
7	0.462	0.445	0.426	0.423	0.426	0.459	0.436	0.446	0.463	0.481	0.436	0.439
8	0.501	0.478	0.466	0.440	0.447	0.499	0.462	0.475	0.462	0.501	0.458	0.448
9	0.565	0.519	0.502	0.485	0.485	0.529	0.500	0.584	0.508	0.550	0.517	0.498
10	0.573	0.537	0.549	0.498	0.492	0.576	0.522	0.527	0.520	0.550	0.523	0.517
11	0.611	0.532	0.524	0.465	0.532	0.603	0.533	0.599	0.538	0.576	0.578	0.542
12	0.632	0.585	0.580	0.565	0.544	0.586	0.565	0.610	0.590	0.590	0.614	0.565

age \ year	2008	2009	2010	2011	2012
0	0.000	0.000	0.000	0.000	0.000
1	0.071	0.071	0.071	0.071	0.071
2	0.157	0.174	0.150	0.188	0.143
3	0.198	0.221	0.211	0.244	0.179
4	0.270	0.268	0.254	0.272	0.248
5	0.323	0.317	0.299	0.341	0.288
6	0.339	0.359	0.351	0.362	0.317
7	0.413	0.395	0.393	0.372	0.351
8	0.431	0.449	0.414	0.406	0.372
9	0.457	0.460	0.445	0.430	0.405
10	0.463	0.517	0.484	0.488	0.436
11	0.506	0.551	0.552	0.526	0.491
12	0.531	0.545	0.571	0.547	0.533

TABLE 2.6.4 NEA Mackerel. NATURAL MORTALITY

Units : NA

year

age	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
0	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
1	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
2	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
3	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
4	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
5	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
6	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
7	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
8	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
9	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
10	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
11	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
12	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15

year

age	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
0	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
1	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
2	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
3	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
4	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
5	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
6	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
7	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
8	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
9	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
10	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
11	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
12	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15

year

age	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
0	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
1	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
2	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
3	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
4	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
5	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
6	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
7	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
8	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
9	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
10	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
11	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
12	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15

TABLE 2.6.5 NEA Mackerel. PROPORTION MATURE

Units : NA

	year														
age	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.07
2	0.53	0.54	0.54	0.55	0.55	0.55	0.56	0.56	0.57	0.57	0.57	0.58	0.58	0.58	0.58
3	0.90	0.90	0.90	0.89	0.89	0.89	0.89	0.89	0.89	0.88	0.88	0.88	0.88	0.88	0.88
4	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.97	0.97	0.97
5	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.97	0.97	0.97
6	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
7	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
8	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
9	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
10	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
11	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
12	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

	year														
age	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
2	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.59
3	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.86	0.86	0.86	0.88
4	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.98	0.98	0.98	0.97
5	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.98	0.98	0.98	0.97
6	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
7	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
8	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
9	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
10	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
11	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
12	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

	year										
age	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.06
2	0.59	0.59	0.59	0.58	0.57	0.58	0.58	0.58	0.58	0.58	0.58
3	0.88	0.88	0.88	0.89	0.89	0.87	0.87	0.86	0.87	0.87	0.86
4	0.97	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
5	0.97	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
6	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
7	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
8	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
9	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
10	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
11	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
12	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

TABLE 2.6.6 NEA Mackerel. FRACTION OF HARVEST BEFORE SPAWNING

Units : NA

year

age	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
0	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421
1	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421
2	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421
3	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421
4	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421
5	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421
6	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421
7	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421
8	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421
9	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421
10	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421
11	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421
12	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421

year

age	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
0	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421
1	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421
2	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421
3	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421
4	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421
5	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421
6	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421
7	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421
8	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421
9	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421
10	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421
11	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421
12	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421

year

age	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
0	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421
1	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421
2	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421
3	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421
4	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421
5	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421
6	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421
7	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421
8	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421
9	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421
10	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421
11	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421
12	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421	0.421

year

age	2008	2009	2010	2011	2012
0	0.421	0.421	0.421	0.421	0.421
1	0.421	0.421	0.421	0.421	0.421
2	0.421	0.421	0.421	0.421	0.421
3	0.421	0.421	0.421	0.421	0.421
4	0.421	0.421	0.421	0.421	0.421
5	0.421	0.421	0.421	0.421	0.421
6	0.421	0.421	0.421	0.421	0.421
7	0.421	0.421	0.421	0.421	0.421
8	0.421	0.421	0.421	0.421	0.421
9	0.421	0.421	0.421	0.421	0.421
10	0.421	0.421	0.421	0.421	0.421
11	0.421	0.421	0.421	0.421	0.421
12	0.421	0.421	0.421	0.421	0.421

TABLE 2.6.7 NEA Mackerel. FRACTION OF NATURAL MORTALITY BEFORE SPAWNING

Units : NA

year

age	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
0	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
1	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
2	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
3	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
4	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
5	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
6	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
7	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
8	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
9	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
10	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
11	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
12	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35

year

age	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
0	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
1	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
2	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
3	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
4	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
5	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
6	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
7	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
8	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
9	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
10	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
11	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
12	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35

year

age	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
0	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
1	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
2	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
3	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
4	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
5	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
6	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
7	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
8	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
9	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
10	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
11	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
12	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35

TABLE 2.6.8 NEA Mackerel. SURVEY INDICES

```
 - Configuration

""
      min       max plusgroup   minyear   maxyear    startf      endf
       NA        NA        NA      1972      2013        NA        NA
Index type : biomass

 - Index Values

Units  :  NA
     year
age   1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985
  all   NA   NA   NA   NA   NA   NA   NA   NA   NA   NA   NA   NA   NA   NA
     year
age   1986 1987 1988 1989 1990 1991    1992 1993 1994    1995 1996 1997    1998
  all   NA   NA   NA   NA   NA   NA 3370000   NA   NA 2840000   NA   NA 3750000
     year
age   1999 2000    2001 2002 2003    2004 2005 2006    2007 2008 2009    2010
  all   NA   NA 2900000   NA   NA 2750000   NA   NA 3646000   NA   NA 4289000
     year
age   2011 2012    2013
  all   NA   NA 5600000

 - Index Variance (Inverse Weights)

Units  :  NA
     year
age   1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985
  all  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1
     year
age   1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999
  all  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1
     year
age   2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013
  all  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1
```

TABLE 2.6.9 NEA Mackerel. STOCK OBJECT CONFIGURATION

```
      min       max plusgroup   minyear   maxyear   minfbar   maxfbar
        0        12        12      1972      2012         4         8
```

TABLE 2.6.10 NEA Mackerel. FLICA CONFIGURATION SETTINGS

```
sep.2       : NA
sep.gradual : TRUE
sr          : FALSE
sr.age      : 0
lambda.age   : 0.0033333 0.033333 0.33333 0.33333 0.33333 0.33333 0.33333 0.33333 0.33333
0.33333 0.33333 0.33333 0
lambda.yr   : 1 1 1 1 1 1 1 1 1 1 1 1
lambda.sr   : 0.01
index.model : linear
index.cor   : -92559631349317830736220086604086468264682600488620284042662244
sep.nyr     : 12
sep.age     : 5
sep.sel     : 1.5
```

TABLE 2.6.11 NEA Mackerel. FLR, R SOFTWARE VERSIONS

```
R version 2.8.1 (2008-12-22)

Package  : FLICA
Version  : 1.4-12
Packaged : 2009-10-08 15:16:26 UTC; mpa
Built    : R 2.9.1; ; 2009-10-08 15:16:27 UTC; windows

Package  : FLAssess
Version  : 1.99-102
Packaged : Mon Mar 23 08:18:19 2009; mpa
Built    : R 2.8.0; i386-pc-mingw32; 2009-03-23 08:18:21; windows

Package  : FLCore
Version  : 3.0
Packaged : Tue Mar 10 04:42:26 2009; theussl
Built    : R 2.8.1; i386-pc-mingw32; 2009-03-10 04:42:28; windows
```

TABLE 2.6.12 NEA Mackerel. STOCK SUMMARY

Year	Recruitment Age 0	TSB	SSB	Fbar (Ages 4-8) f	Landings Tonnes	Landings SOP
1972	2046916	5090763	3778148	0.0196	361262	1.0000
1973	4649382	4979209	3823095	0.1942	570719	1.0000
1974	3864697	4849786	3634393	0.2196	607473	1.0000
1975	4813971	4657051	3354211	0.2328	784329	1.0000
1976	4846818	4371837	3022782	0.2692	828434	1.0000
1977	918120	4067999	2848822	0.2084	620016	1.0000
1978	3176282	3724615	2803629	0.2046	736519	1.0000
1979	5232931	3300209	2350477	0.2704	842739	1.0000
1980	5456818	3004356	1958680	0.2618	734950	1.0000
1981	7115017	3110163	1970891	0.2450	754045	1.0000
1982	1962629	3061317	1913129	0.2388	716987	1.0000
1983	1520121	3197447	2224296	0.2260	672283	1.0000
1984	7295362	2993008	2261824	0.2350	641928	1.0000
1985	3237738	3155335	2187315	0.2302	614371	1.0000
1986	3351691	3182531	2230821	0.2440	602201	1.0000
1987	5038723	3065133	2239987	0.2302	654992	1.0000
1988	3530571	3137372	2244063	0.2528	680491	1.0000
1989	4332807	3224556	2327864	0.1896	585920	1.0000
1990	3131025	3022026	2202435	0.1906	626107	1.0000
1991	3596278	3299847	2447402	0.2348	675665	1.0000
1992	4437460	3411289	2469379	0.2646	760690	1.0000
1993	5197446	3331255	2308057	0.3326	824568	1.0000
1994	4272627	3173727	2113384	0.3740	819087	1.0000
1995	3929031	3318509	2262190	0.3656	756277	1.0000
1996	3999479	3106255	2243860	0.2544	563472	1.0000
1997	3100277	3215065	2312774	0.2518	573029	1.0000
1998	3004942	3051067	2224703	0.2866	666316	1.0000
1999	3210731	3101328	2267372	0.2934	640309	1.0002
2000	2211793	2882980	2061795	0.3374	738606	1.0002
2001	4203807	2807320	2015219	0.4116	737463	1.0001
2002	6229959	2507571	1678284	0.4550	772905	1.0000
2003	3726261	2681843	1669223	0.4672	669600	1.0002
2004	4909416	2519704	1680565	0.4526	650221	1.0005
2005	7587641	2940962	2041533	0.3382	543486	1.0003
2006	7742560	3320070	2203609	0.2826	472652	1.0006
2007	5001910	3704497	2438738	0.3298	579379	1.0000
2008	4804091	3885721	2703212	0.3040	612856	1.0009
2009	3362153	4224627	3067074	0.2958	734889	1.0014
2010	6335877	3928884	2936914	0.3042	869451	1.0033
2011	5458832	4218737	3011225	0.3382	938819	1.0028
2012	410375806	3551142	2459637	0.3262	892762	1.0029

TABLE 2.6.13 NEA Mackerel. ESTIMATED FISHING MORTALITY

Units : f

age	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
0	0.006	0.004	0.008	0.008	0.014	0.007	0.012	0.024	0.007	0.009	0.006	0.005
1	0.008	0.029	0.030	0.021	0.077	0.047	0.048	0.155	0.106	0.066	0.039	0.031
2	0.028	0.019	0.035	0.030	0.101	0.114	0.196	0.111	0.238	0.173	0.132	0.154
3	0.053	0.072	0.048	0.078	0.156	0.119	0.213	0.320	0.151	0.204	0.230	0.180
4	0.098	0.145	0.125	0.103	0.218	0.132	0.200	0.270	0.269	0.101	0.234	0.271
5	0.000	0.162	0.206	0.188	0.161	0.115	0.219	0.263	0.271	0.226	0.105	0.236
6	0.000	0.205	0.185	0.171	0.218	0.129	0.180	0.287	0.222	0.283	0.250	0.103
7	0.000	0.221	0.281	0.426	0.395	0.250	0.159	0.313	0.256	0.268	0.283	0.241
8	0.000	0.238	0.301	0.276	0.354	0.416	0.265	0.219	0.291	0.347	0.322	0.279
9	0.000	0.240	0.304	0.278	0.238	0.281	0.407	0.433	0.248	0.349	0.415	0.274
10	0.000	0.260	0.330	0.302	0.258	0.184	0.487	0.626	0.415	0.454	0.392	0.403
11	0.000	0.243	0.308	0.282	0.242	0.172	0.328	0.939	0.807	0.640	0.542	0.510
12	0.000	0.243	0.308	0.282	0.242	0.172	0.328	0.939	0.807	0.640	0.542	0.510

age	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
0	0.043	0.028	0.016	0.002	0.018	0.016	0.008	0.003	0.011	0.004	0.006	0.004
1	0.027	0.049	0.023	0.015	0.039	0.023	0.042	0.024	0.030	0.037	0.036	0.024
2	0.068	0.021	0.097	0.077	0.064	0.099	0.094	0.079	0.078	0.092	0.079	0.104
3	0.220	0.057	0.046	0.205	0.120	0.122	0.172	0.120	0.173	0.175	0.178	0.159
4	0.228	0.207	0.094	0.084	0.241	0.139	0.164	0.222	0.212	0.281	0.251	0.226
5	0.280	0.215	0.246	0.143	0.140	0.240	0.177	0.207	0.268	0.289	0.336	0.264
6	0.274	0.283	0.262	0.245	0.193	0.124	0.249	0.205	0.250	0.353	0.348	0.363
7	0.149	0.265	0.342	0.290	0.308	0.180	0.145	0.296	0.265	0.381	0.455	0.465
8	0.244	0.181	0.276	0.389	0.382	0.265	0.218	0.244	0.328	0.359	0.480	0.510
9	0.286	0.284	0.173	0.358	0.446	0.358	0.315	0.283	0.388	0.503	0.528	0.626
10	0.331	0.359	0.305	0.383	0.354	0.472	0.277	0.440	0.387	0.538	0.447	0.559
11	0.435	0.397	0.367	0.394	0.452	0.402	0.448	0.406	0.464	0.570	0.572	0.564
12	0.435	0.397	0.367	0.394	0.452	0.402	0.448	0.406	0.464	0.570	0.572	0.564

age	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
0	0.010	0.013	0.022	0.023	0.018	0.003	0.003	0.003	0.003	0.002	0.002	0.002
1	0.039	0.047	0.041	0.032	0.042	0.019	0.020	0.021	0.020	0.015	0.013	0.015
2	0.061	0.075	0.092	0.068	0.076	0.061	0.067	0.069	0.067	0.050	0.042	0.049
3	0.134	0.109	0.137	0.116	0.185	0.152	0.168	0.173	0.167	0.125	0.105	0.122
4	0.179	0.209	0.200	0.184	0.287	0.259	0.286	0.294	0.285	0.213	0.178	0.208
5	0.211	0.225	0.298	0.252	0.308	0.353	0.390	0.401	0.388	0.290	0.242	0.283
6	0.199	0.233	0.282	0.317	0.337	0.447	0.494	0.507	0.491	0.367	0.307	0.358
7	0.368	0.254	0.311	0.343	0.373	0.482	0.533	0.547	0.530	0.396	0.331	0.386
8	0.315	0.338	0.342	0.371	0.382	0.517	0.572	0.587	0.569	0.425	0.355	0.414
9	0.523	0.362	0.404	0.399	0.378	0.522	0.577	0.593	0.574	0.429	0.358	0.418
10	0.475	0.442	0.376	0.462	0.434	0.566	0.626	0.643	0.623	0.465	0.389	0.454
11	0.473	0.481	0.511	0.463	0.553	0.530	0.586	0.601	0.582	0.435	0.364	0.424
12	0.473	0.481	0.511	0.463	0.553	0.530	0.586	0.601	0.582	0.435	0.364	0.424

age	2008	2009	2010	2011	2012
0	0.002	0.002	0.002	0.002	0.002
1	0.014	0.013	0.014	0.015	0.015
2	0.045	0.044	0.045	0.050	0.048
3	0.112	0.109	0.113	0.125	0.121
4	0.191	0.186	0.192	0.213	0.205
5	0.261	0.254	0.261	0.290	0.280
6	0.330	0.321	0.330	0.367	0.354
7	0.356	0.346	0.356	0.396	0.382
8	0.382	0.372	0.382	0.425	0.410
9	0.385	0.375	0.386	0.429	0.414
10	0.418	0.407	0.419	0.465	0.449
11	0.391	0.381	0.392	0.435	0.420
12	0.391	0.381	0.392	0.435	0.420

TABLE 2.6.14 NEA Mackerel. ESTIMATED POPULATION ABUNDANCE

Units : NA

age	1972	1973	1974	1975	1976	1977	1978	1979	1980
0	2046916	4649382	3864697	4813971	4846818	918120	3176282	5232931	5456818
1	4941057	1751873	3986007	3299242	4109901	4113766	784601	2701765	4397903
2	2024604	4220389	1464983	3330651	2781392	3275539	3378440	643343	1991755
3	4038713	1694735	3563446	1216999	2781121	2163195	2515024	2389388	495502
4	7494845	3296031	1357719	2923146	969227	2047531	1652200	1749327	1493861
5	0	5848235	2452952	1031134	2270549	670802	1543838	1163891	1149478
6	0	0	4280193	1718860	735232	1663584	514652	1067980	770113
7	0	0	0	3061356	1246899	509120	1259165	370020	690083
8	0	0	0	0	1720674	722925	341181	924470	232933
9	0	0	0	0	0	1039050	410329	225357	638926
10	0	0	0	0	0	0	675448	235155	125838
11	0	0	0	0	0	0	0	357185	108255
12	0	0	0	0	0	0	0	0	202079

age	1981	1982	1983	1984	1985	1986	1987	1988	1989
0	7115017	1962629	1520121	7295362	3237738	3351691	5038723	3530571	4332807
1	4666049	6071421	1678889	1301584	6013041	2710956	2838508	4330007	2985374
2	3404566	3760286	5027524	1400640	1090725	4926334	2279482	2405942	3585447
3	1351114	2465710	2835956	3708429	1125840	919436	3847096	1816894	1943344
4	366767	948598	1685605	2039804	2561026	914979	755806	2697928	1387599
5	982591	285303	645882	1106015	1397457	1792569	716665	598048	1824603
6	754574	674857	220992	438980	719656	969656	1206420	534492	447281
7	530687	489361	452448	171534	287252	466815	642410	812382	379299
8	459636	349305	317313	306117	127208	189628	285342	413854	513618
9	149899	279747	217868	206582	206359	91398	123894	166396	243207
10	429095	91011	158966	142565	133545	133688	66151	74529	91681
11	71500	234592	52921	91401	88109	80242	84794	38803	45037
12	451101	399209	353894	210046	319080	283481	207961	169291	116006

age	1990	1991	1992	1993	1994	1995	1996	1997	1998
0	3131025	3596278	4437460	5197446	4272627	3929031	3999479	3100277	3004942
1	3668676	2672428	3086071	3779093	4455545	3653973	3368069	3407208	2635060
2	2509989	3027470	2246012	2578763	3133977	3698443	3069460	2787891	2798857
3	2796510	1966093	2408980	1788438	2024846	2492349	2867721	2485495	2226876
4	1480444	2027079	1501192	1743980	1292685	1458901	1830472	2159798	1918595
5	1039254	1081699	1397689	1045643	1133230	865534	1001487	1317313	1508694
6	1235491	749534	756649	920192	674385	697236	572350	697747	905727
7	339914	828688	525734	507047	556266	409788	417555	403587	475737
8	272720	253200	530516	347281	298109	303810	221535	248832	269410
9	339299	188794	170733	328810	208714	158820	157036	139149	152790
10	146362	213149	122398	99717	171188	105927	73062	80093	83366
11	49214	95455	118158	71577	50109	94230	52106	39110	44293
12	82795	170050	196771	167983	141315	98681	87013	70017	61369

age	1999	2000	2001	2002	2003	2004	2005	2006	2007
0	3210731	2211793	4203807	6229959	3726261	4909416	7587641	7742560	5001910
1	2529736	2701416	1870028	3608112	5345569	3197022	4212555	6515695	6651263
2	2175978	2109176	2230261	1580013	3042598	4505249	2696229	3570989	5537283
3	2196279	1749718	1683061	1806119	1271340	2443751	3626376	2207263	2947695
4	1671889	1683370	1251346	1243982	1313678	920519	1779024	2753912	1711276
5	1352542	1196930	1087905	831182	804027	842541	595854	1237412	1984160
6	964309	904473	757349	657783	484197	463474	491817	383624	835840
7	587805	604527	555539	417009	345527	250980	244088	293194	243010
8	300163	359166	358309	295355	210727	172116	127182	141379	181313
9	164744	178327	211085	183841	143499	100816	83874	71543	85322
10	87837	95117	105153	107796	88857	68287	48875	46999	43037
11	49256	47620	53032	51379	49620	40217	31536	26411	27429
12	93746	86093	105900	97117	73055	43955	32029	35424	41969

age	2008	2009	2010	2011	2012
0	4804091	3362153	6335877	5458832	410375806
1	4295518	4126363	2888000	5442040	4687637
2	5640486	3646984	3504621	2451924	4613246
3	4538912	4641263	3004446	2883584	2007294
4	2245709	3491267	3580505	2310604	2189912
5	1196807	1596379	2494239	2544530	1607262
6	1286990	793723	1065962	1653562	1638374
7	502995	796560	495516	659446	985875
8	142191	303370	484915	298706	382007
9	103111	83537	180019	284732	168052
10	48340	60368	49404	105337	159572
11	23535	27394	34586	27980	56930
12	31722	16729	28411	32711	37956

TABLE 2.6.15 NEA Mackerel. SURVIVORS AFTER TERMINAL YEAR

Units : NA

age	2013
0	NA
1	352429398
2	3975919
3	3783518
4	1531324
5	1535062
6	1045782
7	989850
8	579322
9	218240
10	95651
11	87703
12	53679

TABLE 2.6.16 NEA Mackerel. FITTED SELECTION PATTERN

Units : NA

age	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
0	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008
1	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052
2	0.173	0.173	0.173	0.173	0.173	0.173	0.173	0.173	0.173	0.173	0.173	0.173
3	0.431	0.431	0.431	0.431	0.431	0.431	0.431	0.431	0.431	0.431	0.431	0.431
4	0.734	0.734	0.734	0.734	0.734	0.734	0.734	0.734	0.734	0.734	0.734	0.734
5	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
6	1.265	1.265	1.265	1.265	1.265	1.265	1.265	1.265	1.265	1.265	1.265	1.265
7	1.364	1.364	1.364	1.364	1.364	1.364	1.364	1.364	1.364	1.364	1.364	1.364
8	1.465	1.465	1.465	1.465	1.465	1.465	1.465	1.465	1.465	1.465	1.465	1.465
9	1.478	1.478	1.478	1.478	1.478	1.478	1.478	1.478	1.478	1.478	1.478	1.478
10	1.603	1.603	1.603	1.603	1.603	1.603	1.603	1.603	1.603	1.603	1.603	1.603
11	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500
12	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500

TABLE 2.6.17 NEA Mackerel. PREDICTED CATCH IN NUMBERS

Units : NA

year

age	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
0	10707	16997	29277	36171	62510	6077	34623	114529	33101	56682
1	34979	46267	108077	62908	282818	175220	34513	360698	411327	276229
2	51652	74544	47410	92385	249293	328732	560738	62909	393025	502365
3	194461	109015	155390	84509	374245	226560	449338	609522	64549	231814
4	650980	415015	148543	265129	176793	236116	279236	385578	328206	32814
5	0	814518	424462	164673	314261	67758	282158	250755	254172	184867
6	0	0	673317	251420	133822	186619	78877	248099	142978	173349
7	0	0	0	991632	379790	105004	172213	92655	145385	116328
8	0	0	0	0	478925	229803	73933	169605	54778	125548
9	0	0	0	0	0	236966	127975	73900	130771	41186
10	0	0	0	0	0	0	243333	102363	39920	146186
11	0	0	0	0	0	0	0	204291	56210	31639
12	0	0	0	0	0	0	0	0	104927	199615

year

age	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
0	11180	7333	287287	81799	49983	7403	57644	65400	24246	10007
1	213936	47914	31901	268960	58126	40126	152656	64263	140534	58459
2	432867	668909	86064	20893	424563	156670	137635	312739	209848	212521
3	472457	433744	682491	58346	38387	663378	190403	207689	410751	206421
4	184581	373262	387582	445357	76545	56680	538394	167588	208146	375451
5	26544	126533	251503	252217	364119	89003	72914	362469	156742	188623
6	138970	20175	98063	165219	208021	244570	87323	48696	254015	129145
7	112476	90151	22086	62363	126174	150588	201021	58116	42549	197888
8	89672	72031	61813	19562	42569	85863	122496	111251	49698	51077
9	88726	48668	47925	47560	13533	34795	55913	68240	85447	43415
10	27552	49252	37482	37607	32786	19658	20710	32228	33041	70839
11	91743	19745	30105	26965	22971	25747	13178	13904	16587	29743
12	156121	132040	69183	97652	81153	63146	57494	35814	27905	52986

year

age	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
0	43447	19354	25368	14759	37956	36012	61127	67003	36345	10939
1	83583	128144	147315	81529	119852	144390	99352	73597	102407	31873
2	156292	210319	221489	340898	168882	186481	229767	132994	142898	122531
3	356209	266677	306979	340215	333365	238426	264566	223639	275376	221207
4	266591	398240	267420	275031	279182	378881	323186	261778	390858	266118
5	306143	244285	301346	186855	177667	246781	361945	281041	295516	301890
6	156070	255472	184925	197856	96303	135059	207619	244212	241550	254787
7	113899	149932	189847	142342	119831	84378	118388	159019	175608	198409
8	138458	97746	106108	113413	55812	66504	72745	86739	106291	135251
9	51208	121400	80054	69191	59801	39450	47353	50613	52394	80234
10	36612	38794	57622	42441	25803	26735	24386	30363	31280	42511
11	40956	29067	20407	37960	18353	13950	16551	17048	18918	20385
12	68205	68217	57551	39753	30648	24974	22932	32446	34202	40706

year

age	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
0	17917	11005	14046	16237	13832	10429	9231	6292	12192	11678
1	67915	103304	59866	59125	76427	90978	54173	50687	36474	76358
2	95659	189011	271383	122426	135886	245136	230525	145236	143434	111300
3	260412	187845	350652	396940	203673	314864	448815	447562	297488	315543
4	288747	312027	212697	317831	417545	298657	363938	552297	581011	412686
5	250664	247823	252996	139933	248042	455595	255858	333413	533900	597409
6	239503	179980	168065	141025	94416	234536	337094	203264	279541	474026
7	160948	136086	96480	74497	76963	72601	140405	217460	138483	201214
8	120300	87549	69830	41132	39407	57419	42112	87898	143786	96582
9	75388	60019	41180	27324	20093	27219	30767	24386	53778	92737
10	46929	39436	29616	16989	14119	14655	15414	18839	15772	36607
11	21300	20979	16607	10395	7509	8854	7108	8094	10457	9221
12	40260	30887	18151	10558	10071	13548	9580	4943	8590	10780

year

age	2012
0	846235
1	63416
2	202027
3	212183
4	378379
5	365508
6	455475
7	291852
8	119888
9	53130
10	53859
11	18213
12	12143

TABLE 2.6.18 NEA Mackerel. CATCH RESIDUALS

Units : Thousands NA

age	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
0	0.867	1.369	0.269	-1.000	-1.175	1.439	0.388	1.025	0.968	0.630
1	0.235	1.185	0.567	-0.889	-0.290	-0.098	-0.136	-0.254	-0.376	0.256
2	0.260	-0.316	0.339	0.451	0.075	0.195	-0.256	-0.385	-0.290	-0.060
3	0.057	0.343	-0.748	0.354	0.511	-0.263	-0.323	-0.149	0.002	0.008
4	0.110	0.192	-0.072	-0.398	-0.093	0.115	-0.381	-0.265	0.108	0.233
5	0.026	0.046	-0.072	-0.033	-0.167	-0.245	-0.015	0.006	-0.039	0.135
6	-0.095	-0.011	0.003	-0.197	-0.162	0.025	-0.156	-0.283	0.095	0.017
7	-0.016	-0.062	-0.028	-0.139	-0.163	-0.043	0.037	-0.130	-0.118	0.031
8	-0.118	-0.012	0.062	-0.128	-0.079	-0.170	0.021	0.300	-0.182	-0.342
9	-0.105	0.058	0.220	-0.091	-0.140	-0.067	0.039	0.042	0.192	-0.158
10	0.000	-0.070	0.149	0.103	0.096	-0.012	0.116	0.219	-0.237	0.297
11	0.008	0.014	0.203	-0.076	-0.279	0.102	0.287	-0.047	-0.086	-0.511
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

age	2011	2012
0	-1.306	-3.474
1	-0.266	0.055
2	-0.059	0.007
3	0.006	0.017
4	0.119	0.092
5	0.083	0.214
6	0.024	0.112
7	0.191	0.100
8	0.153	0.179
9	-0.552	0.277
10	-0.373	-0.571
11	0.294	-0.418
12	0.000	0.000

Table 2.6.2.1. NEA Mackerel stock summary from the ICA assessment implementing a stock recruitment relationship (weighted by a lambda.SR parameter value of 0.17).

Year	Recruitment Age 0	TSB	SSB	Fbar (Ages 4-8) f	Landings Tonnes	Landings SOP
1972	2037221	5064651	3758841	0.0198	361262	1.0000
1973	4633360	4951960	3801249	0.1938	570719	1.0000
1974	3845983	4821010	3609734	0.2196	607473	1.0000
1975	4798992	4626801	3328494	0.2340	784329	1.0000
1976	4832941	4341142	2996073	0.2718	828434	1.0000
1977	910944	4036872	2821718	0.2106	620016	1.0000
1978	3168189	3693993	2775902	0.2066	736519	1.0000
1979	5223162	3270400	2322825	0.2728	842739	1.0000
1980	5441207	2977390	1933850	0.2646	734950	1.0000
1981	7096314	3079828	1943422	0.2476	754045	1.0000
1982	1952043	3033107	1887778	0.2420	716987	1.0000
1983	1512941	3171972	2201764	0.2286	672283	1.0000
1984	7282470	2970315	2241524	0.2370	641928	1.0000
1985	3228840	3128720	2163106	0.2324	614371	1.0000
1986	3344683	3159840	2210705	0.2462	602201	1.0000
1987	5031650	3045688	2222567	0.2326	654992	1.0000
1988	3523506	3118115	2226484	0.2552	680491	1.0000
1989	4326489	3207095	2312162	0.1912	585920	1.0000
1990	3127747	3006577	2188495	0.1920	626107	1.0000
1991	3593490	3282337	2431388	0.2360	675665	1.0000
1992	4434950	3395328	2454789	0.2658	760690	1.0000
1993	5195108	3317931	2295488	0.3346	824568	1.0000
1994	4272455	3162112	2102461	0.3760	819087	1.0000
1995	3929659	3308087	2252380	0.3676	756277	1.0000
1996	4005946	3097594	2235425	0.2560	563472	1.0000
1997	3109145	3208999	2306620	0.2526	573029	1.0000
1998	3013773	3047323	2220284	0.2870	666316	1.0000
1999	3229129	3100004	2264883	0.2936	640309	1.0002
2000	2239066	2884587	2061576	0.3374	738606	1.0002
2001	4250094	2813544	2016789	0.4140	737463	1.0001
2002	6168462	2518134	1683091	0.4564	772905	1.0000
2003	3863827	2693348	1679987	0.4680	669600	1.0002
2004	5006617	2537339	1692258	0.4510	650221	1.0005
2005	7450506	2976018	2064250	0.3338	543486	1.0003
2006	7744567	3357075	2240486	0.2774	472652	1.0006
2007	5482996	3737420	2477374	0.3200	579379	1.0000
2008	5831421	3955802	2750887	0.2894	612856	1.0009
2009	5015068	4403771	3167262	0.2756	734889	1.0014
2010	10460737	4283735	3153710	0.2670	869451	1.0033
2011	7699980	5050913	3505617	0.2714	938819	1.0028
2012	4307930	4682488	3241787	0.2378	892762	1.0029

Table 2.6.2.2. NEA Mackerel stock summary from the ICA assessment using higher weights for the catch residuals of ages 0 and 1.

Year	Recruitment Age 0	TSB	SSB	Fbar (Ages 4-8) f	Landings Tonnes	Landings SOP
1972	2038941	5068199	3761196	0.0198	361262	1.0000
1973	4636074	4955746	3804020	0.1932	570719	1.0000
1974	3847890	4825091	3613910	0.2186	607473	1.0000
1975	4800809	4631054	3332213	0.2332	784329	1.0000
1976	4834717	4345442	2999961	0.2714	828434	1.0000
1977	911849	4041207	2825284	0.2104	620016	1.0000
1978	3169234	3698248	2779801	0.2062	736519	1.0000
1979	5224697	3274521	2326732	0.2724	842739	1.0000
1980	5443392	2981239	1937518	0.2640	734950	1.0000
1981	7098615	3084040	1947334	0.2472	754045	1.0000
1982	1953241	3037211	1891557	0.2416	716987	1.0000
1983	1513999	3175669	2205115	0.2282	672283	1.0000
1984	7284897	2973420	2244155	0.2370	641928	1.0000
1985	3230966	3131958	2165912	0.2322	614371	1.0000
1986	3346821	3162914	2213357	0.2458	602201	1.0000
1987	5034262	3048530	2224985	0.2322	654992	1.0000
1988	3525914	3121137	2228997	0.2550	680491	1.0000
1989	4328761	3210180	2314791	0.1910	585920	1.0000
1990	3124538	3009601	2191317	0.1912	626107	1.0000
1991	3579448	3285556	2434370	0.2358	675665	1.0000
1992	4429344	3397052	2457375	0.2656	760690	1.0000
1993	5228648	3317703	2296653	0.3340	824568	1.0000
1994	4324929	3163533	2102540	0.3752	819087	1.0000
1995	3985285	3314110	2253294	0.3674	756277	1.0000
1996	4067608	3109840	2241542	0.2556	563472	1.0000
1997	3158108	3231622	2320618	0.2528	573029	1.0000
1998	3043080	3076696	2241606	0.2868	666316	1.0000
1999	3211805	3139787	2296286	0.2926	640309	1.0002
2000	2269096	2924890	2098219	0.3314	738606	1.0002
2001	4662860	2858201	2045517	0.4218	737463	1.0001
2002	6725027	2561522	1672588	0.4992	772905	1.0000
2003	3593867	2746439	1674918	0.4852	669600	1.0002
2004	4920217	2601344	1753572	0.4166	650221	1.0005
2005	7649117	3082098	2168414	0.3246	543486	1.0003
2006	8226498	3452350	2313840	0.2798	472652	1.0006
2007	5450503	3832274	2528983	0.3162	579379	1.0000
2008	5580033	4059676	2824943	0.2816	612856	1.0009
2009	5268723	4500210	3267689	0.2628	734889	1.0014
2010	9800108	4381878	3236682	0.2622	869451	1.0033
2011	9411580	5112091	3600654	0.2508	938819	1.0028
2012	20905062	4821198	3302709	0.2290	892762	1.0029

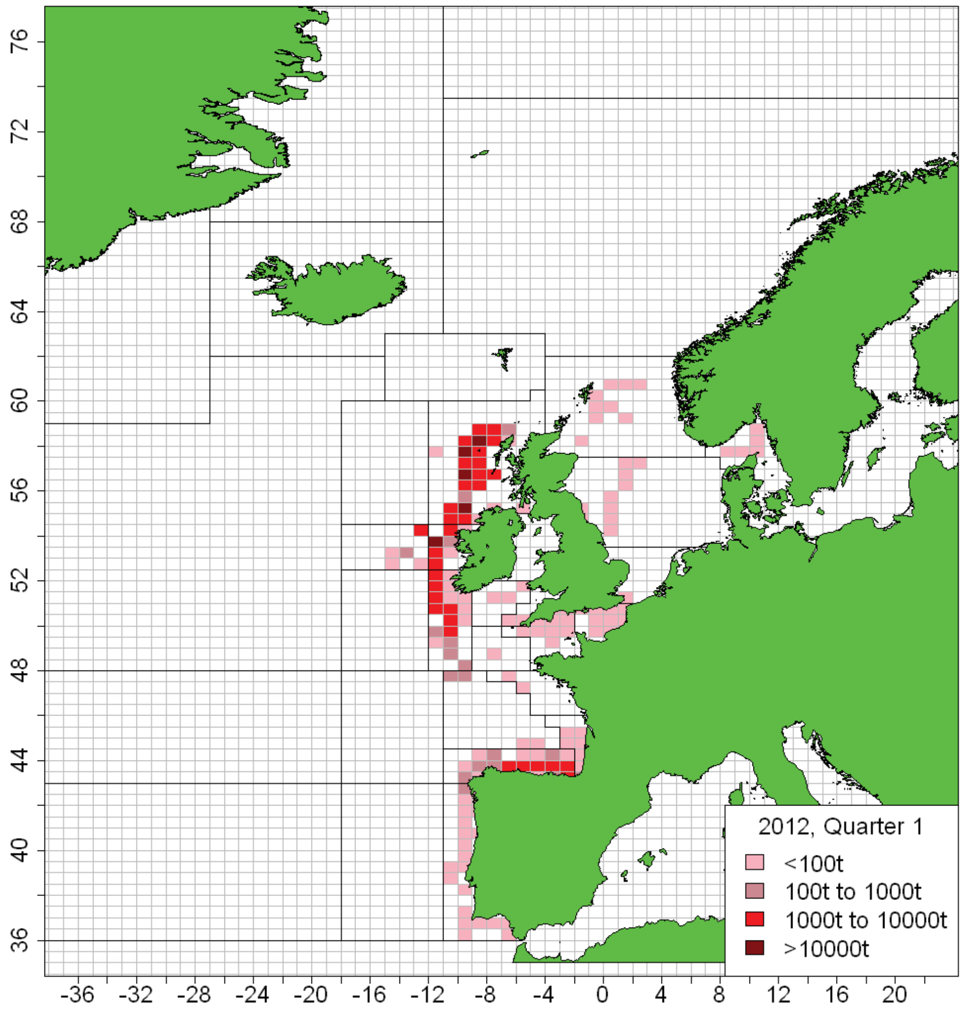

Figure 2.3.2.1. NE Atlantic Mackerel. Commercial catches in 2012, quarter1.

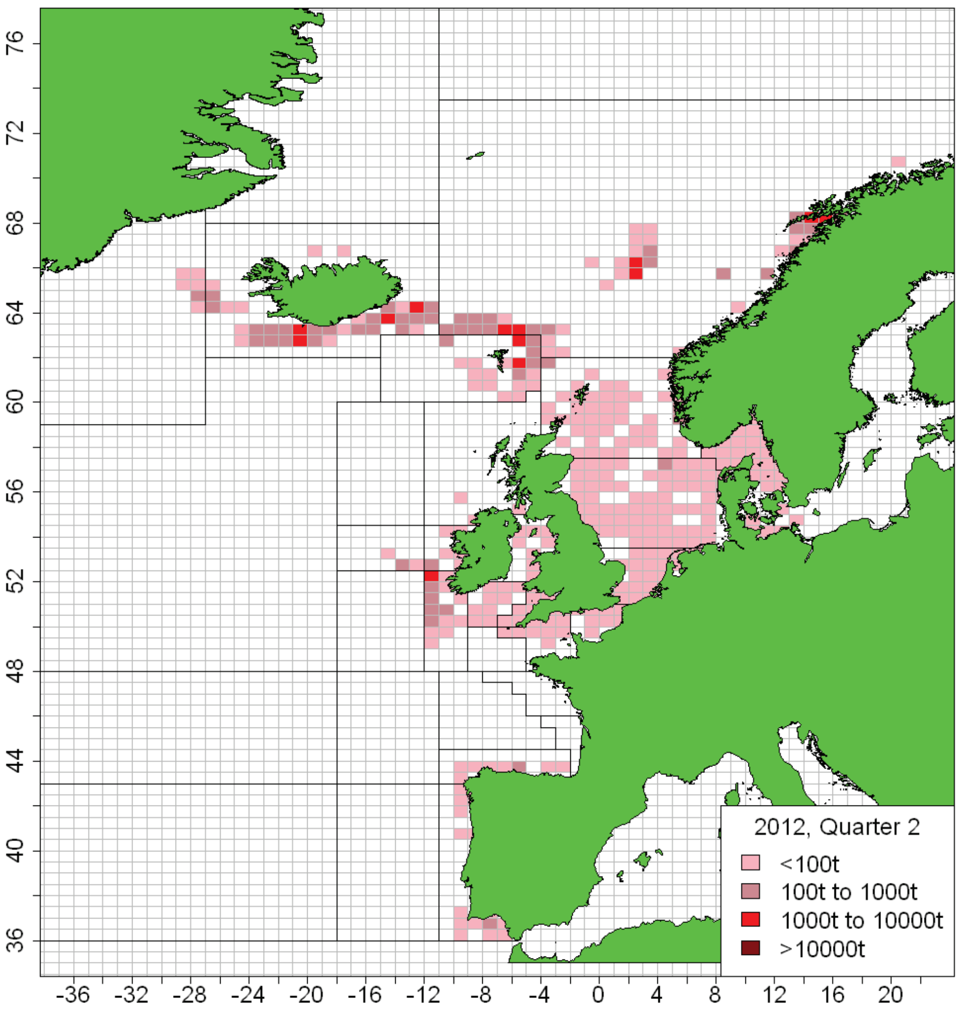

Figure 2.3.2.2. NE Atlantic Mackerel. Commercial catches in 2012, quarter 2.

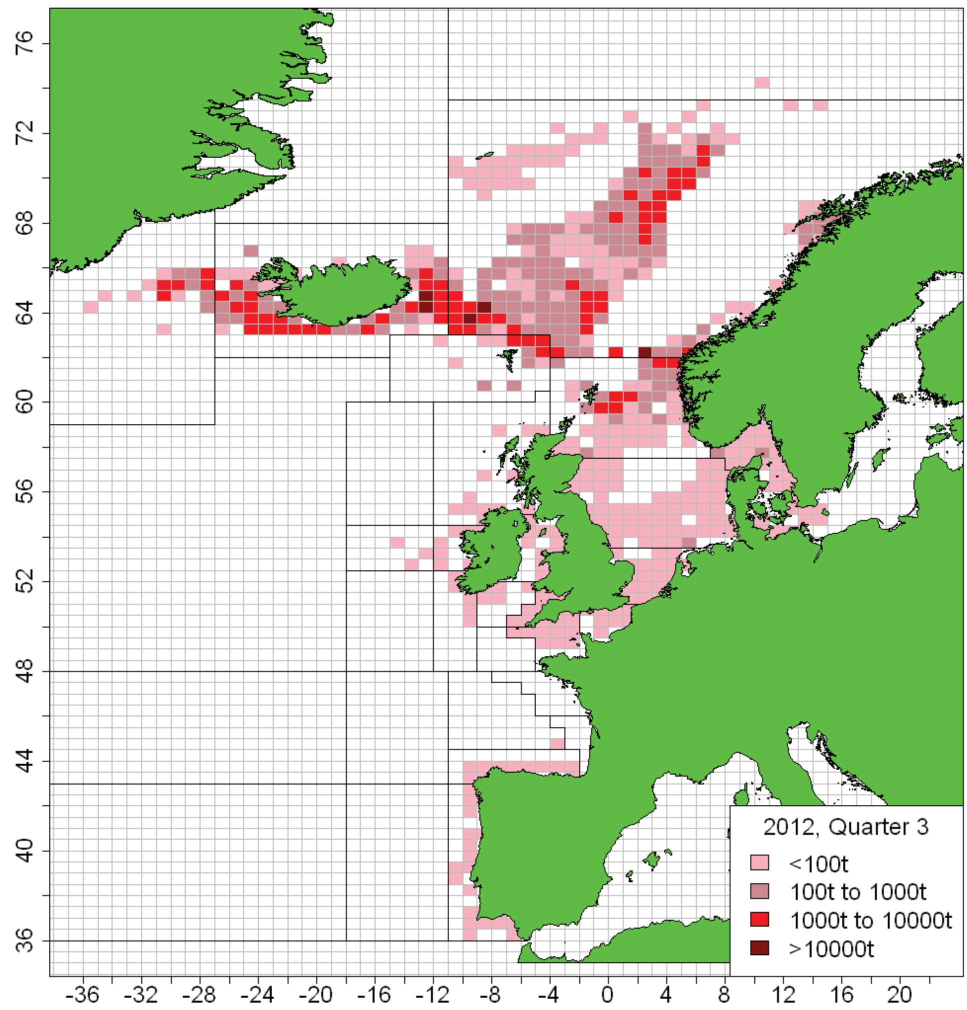

Figure 2.3.2.3 NE Atlantic Mackerel. Commercial catches in 2012, quarter 3.

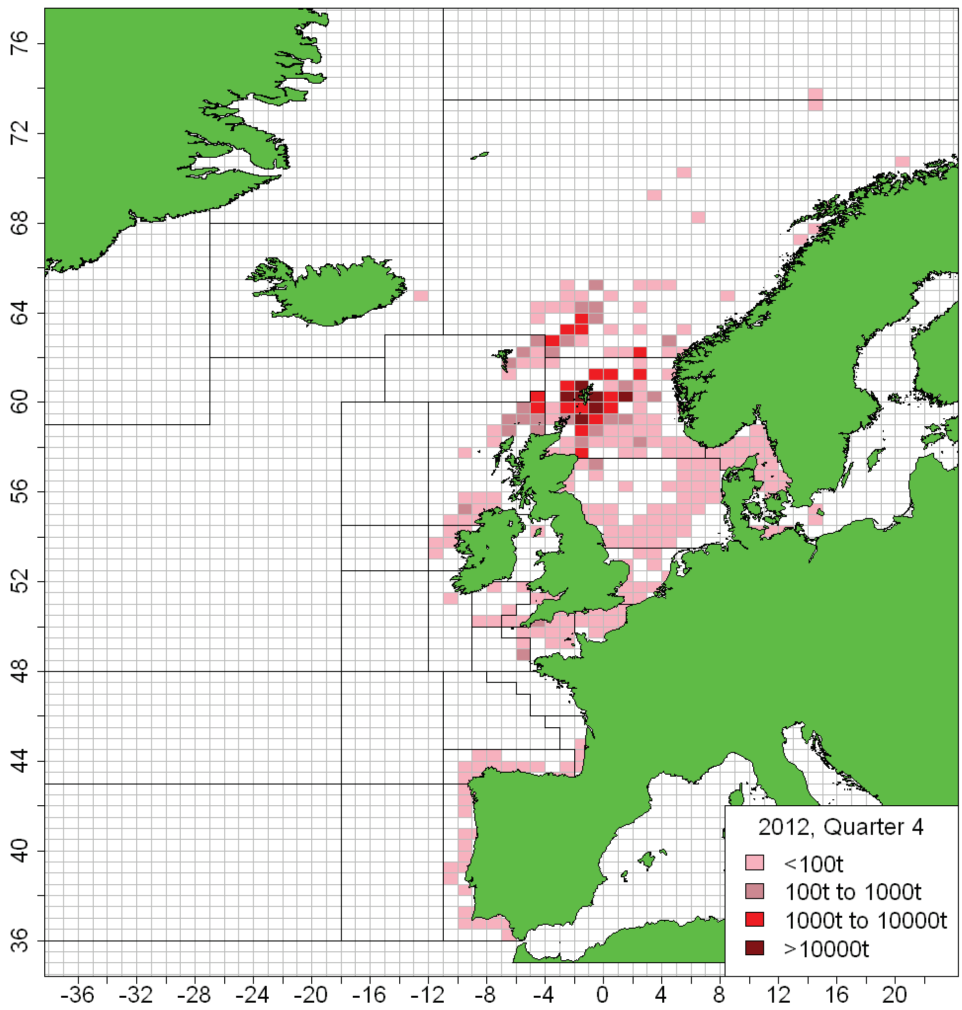

Figure 2.3.2.4. NE Atlantic Mackerel. Commercial catches in 2012, quarter 4.

Figure 2.3.4.1. NEA mackerel (Southern component). Effort data by fleets.

Figure 2.3.4.2. NEA mackerel (Southern component). CPUE index by fleet.

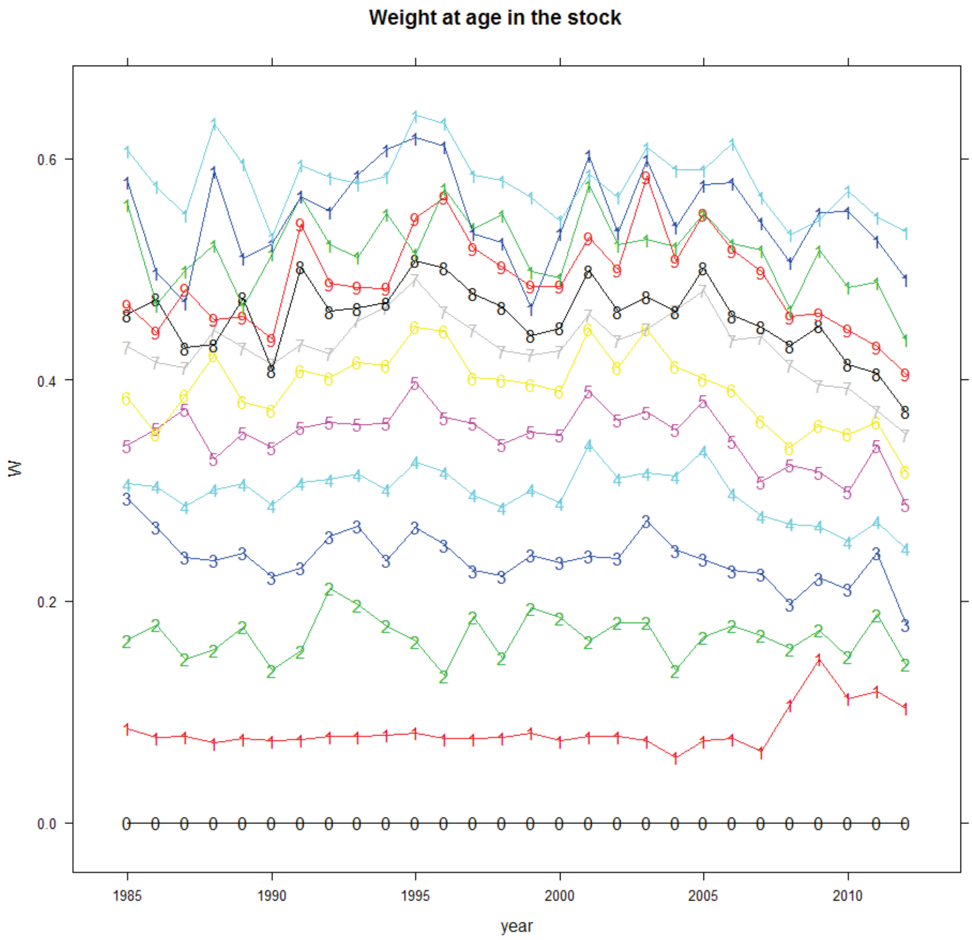

Figure 2.4.2.1. NE Atlantic mackerel. Stock weights-at-age for NE Atlantic mackerel.

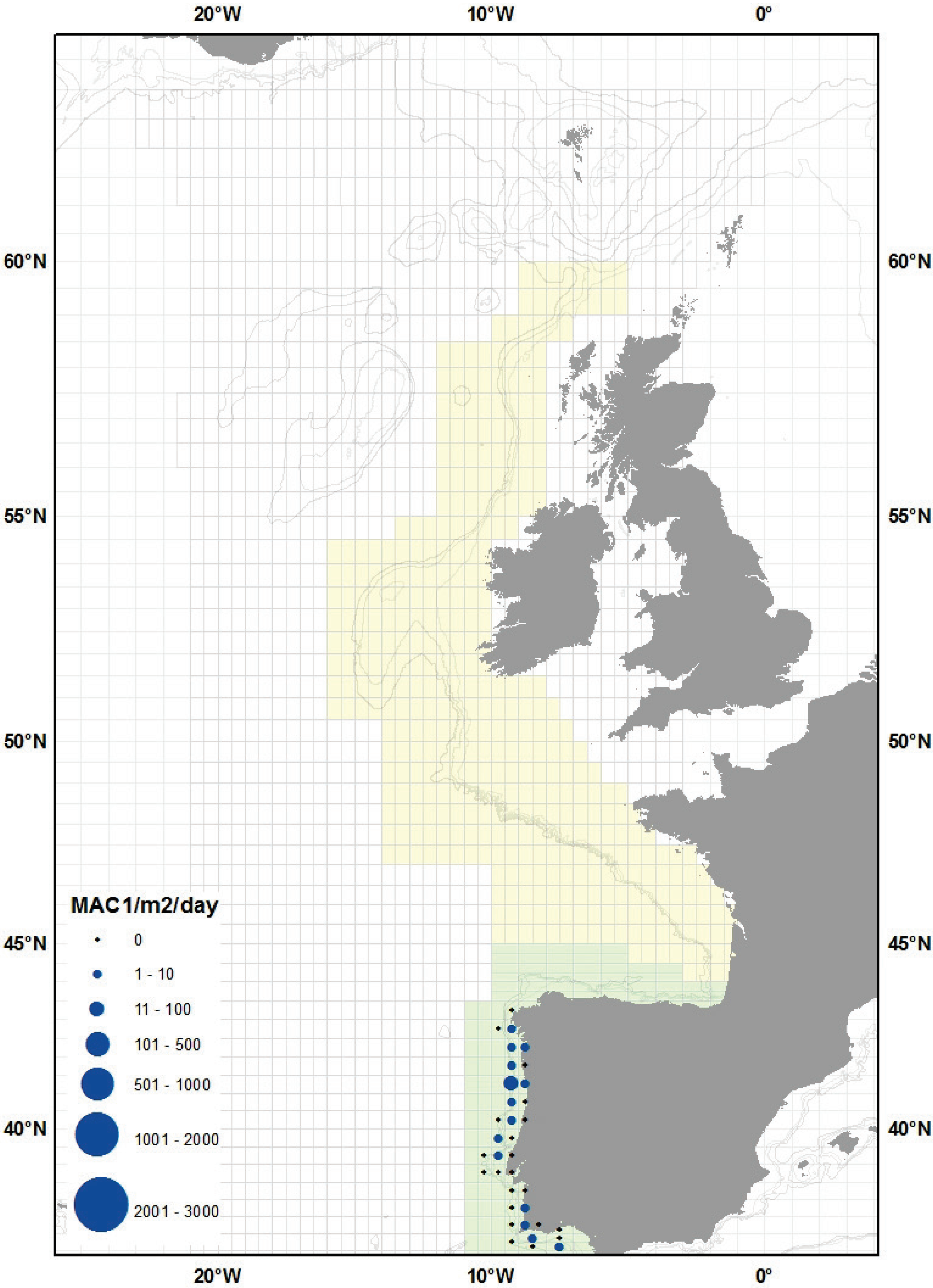

Figure 2.5.1.1: NE Atlantic Mackerel. Mackerel egg production by half rectangle for Period 1 (10th February – 19th February). Filled blue circles represent observed values, filled red circles represent interpolated values, black crosses represent observed zeroes, and red crosses interpolated zeroes.

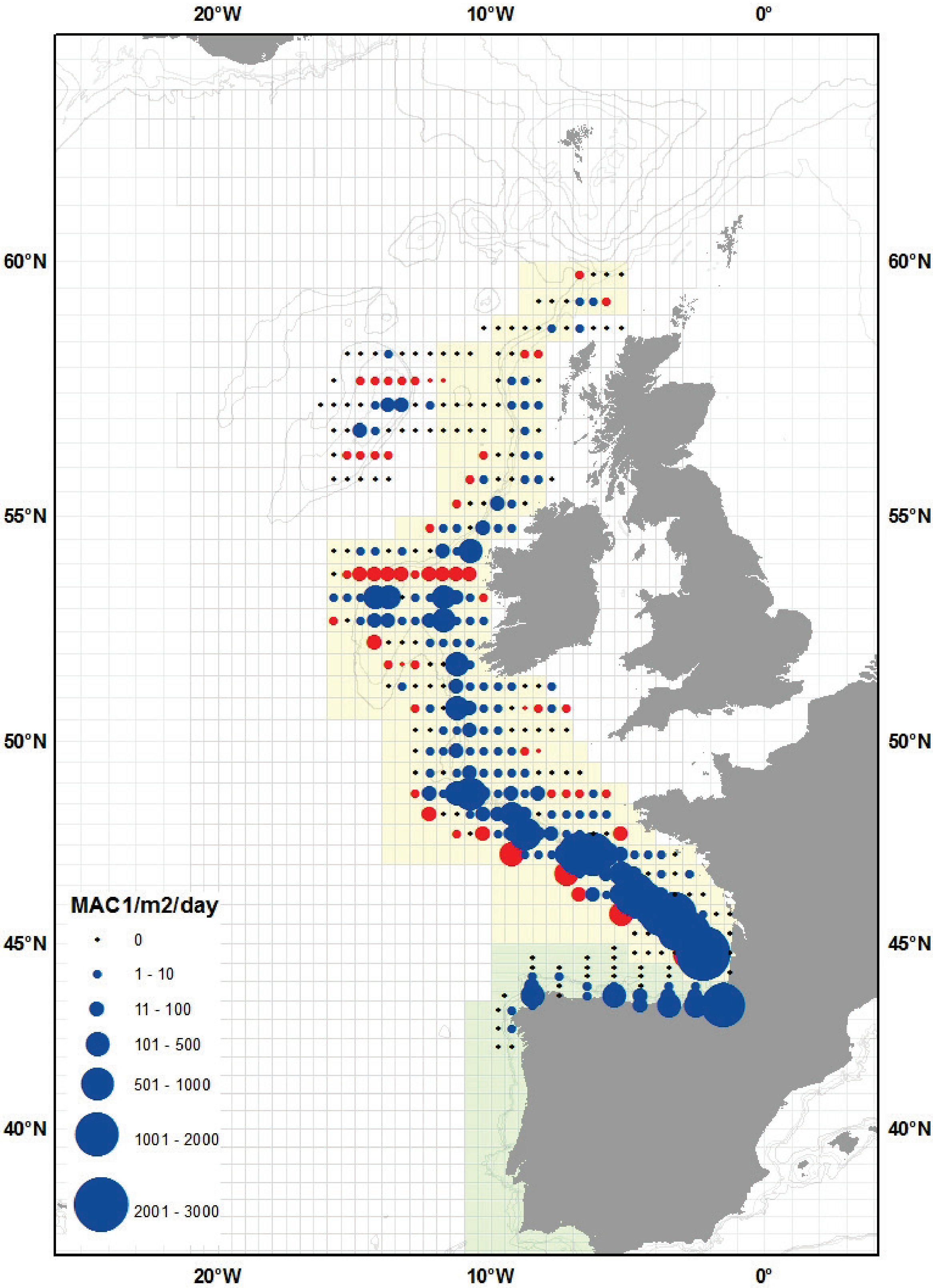

Figure 2.5.1.2: NE Atlantic Mackerel. Mackerel egg production by half rectangle for Period 2 (19th February – 27 th March). Filled blue circles represent observed values, filled red circles represent interpolated values, black crosses represent observed zeroes, and red crosses interpolated zeroes.

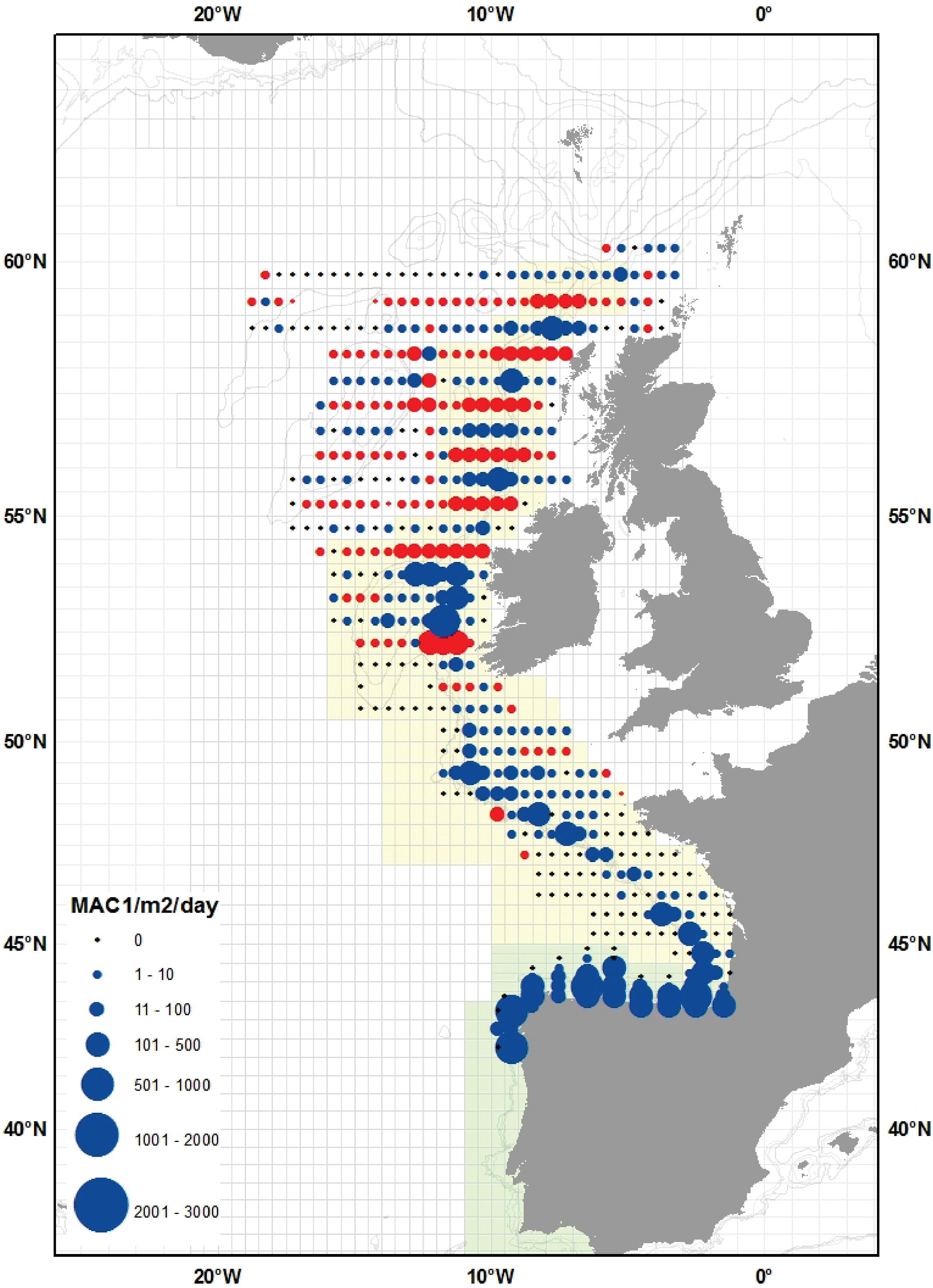

Figure 2.5.1.3: NE Atlantic Mackerel. Mackerel egg production by half rectangle for Period 3 (28th March – 6th May). Filled blue circles represent observed values, filled red circles represent interpolated values, black crosses represent observed zeroes, and red crosses interpolated zeroes.

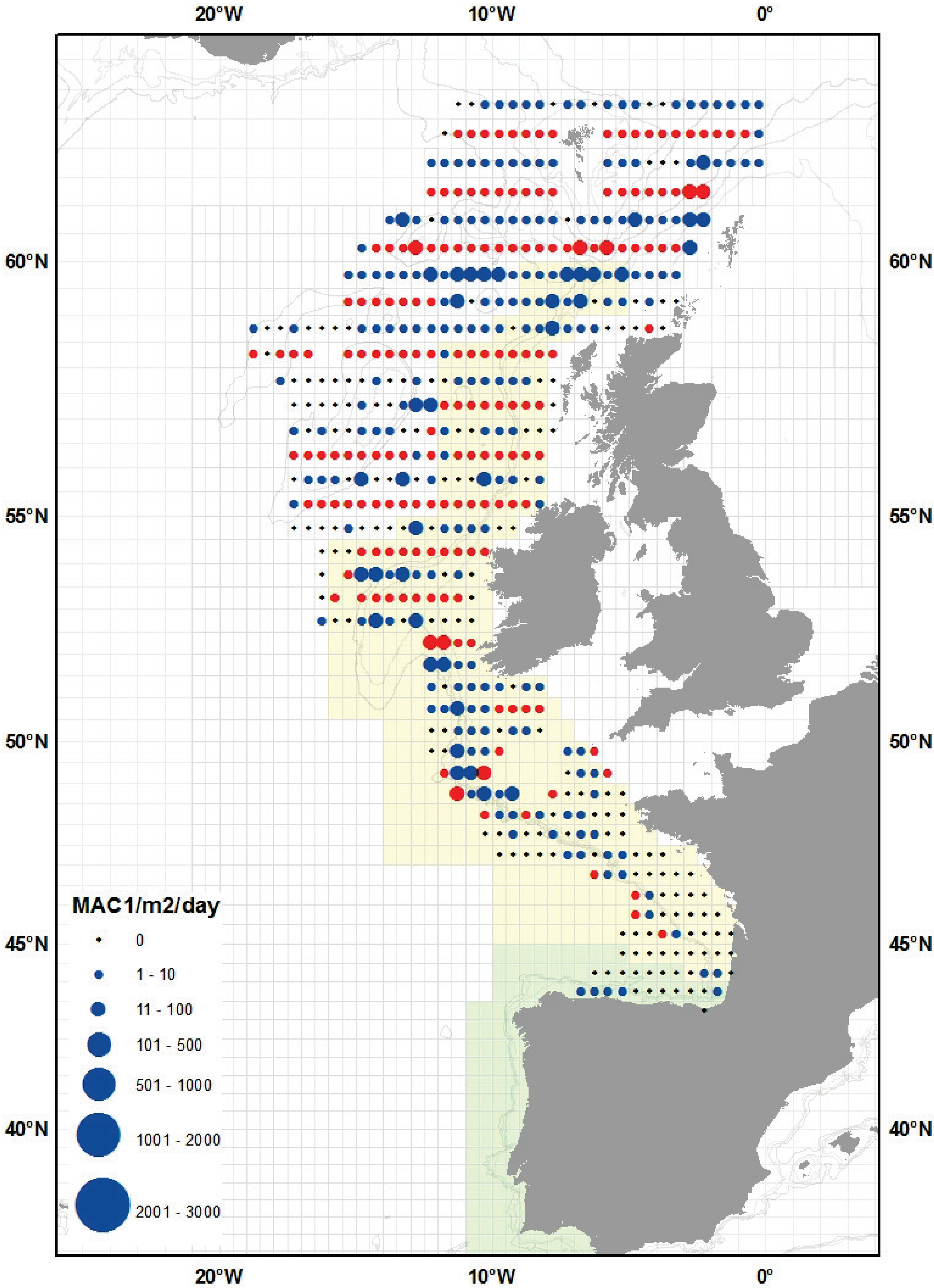

Figure 2.5.1.4: NE Atlantic Mackerel. Mackerel egg production by half rectangle for Period 4 (7th May – 3rd June). Filled blue circles represent observed values, filled red circles represent interpolated values, black crosses represent observed zeroes, and red crosses interpolated zeroes.

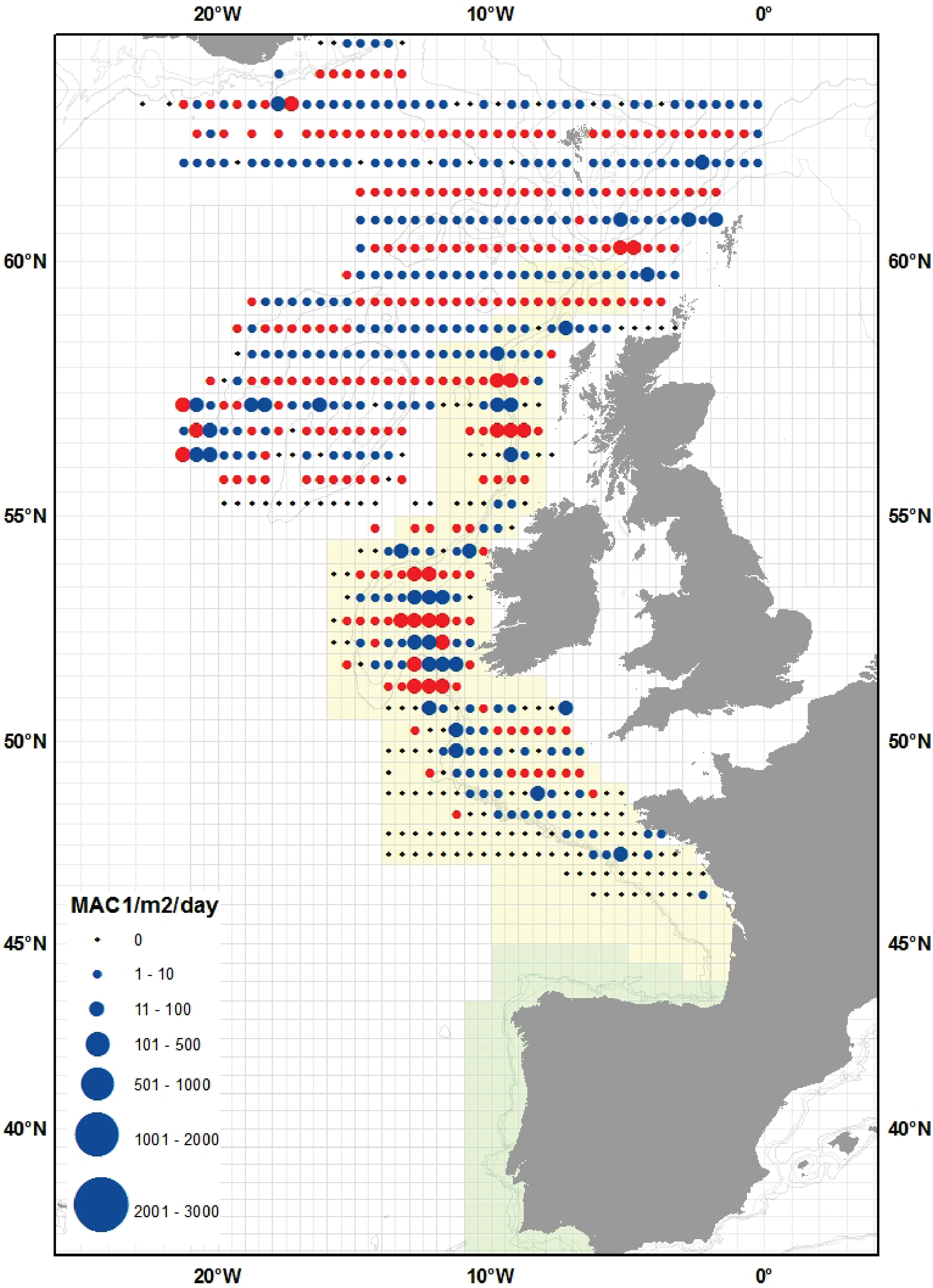

Figure 2.5.1.5: NE Atlantic Mackerel. Mackerel egg production by half rectangle for Period 5 (4th June – 26th June). Filled blue circles represent observed values, filled red circles represent interpolated values, black crosses represent observed zeroes, and red crosses interpolated zeroes.

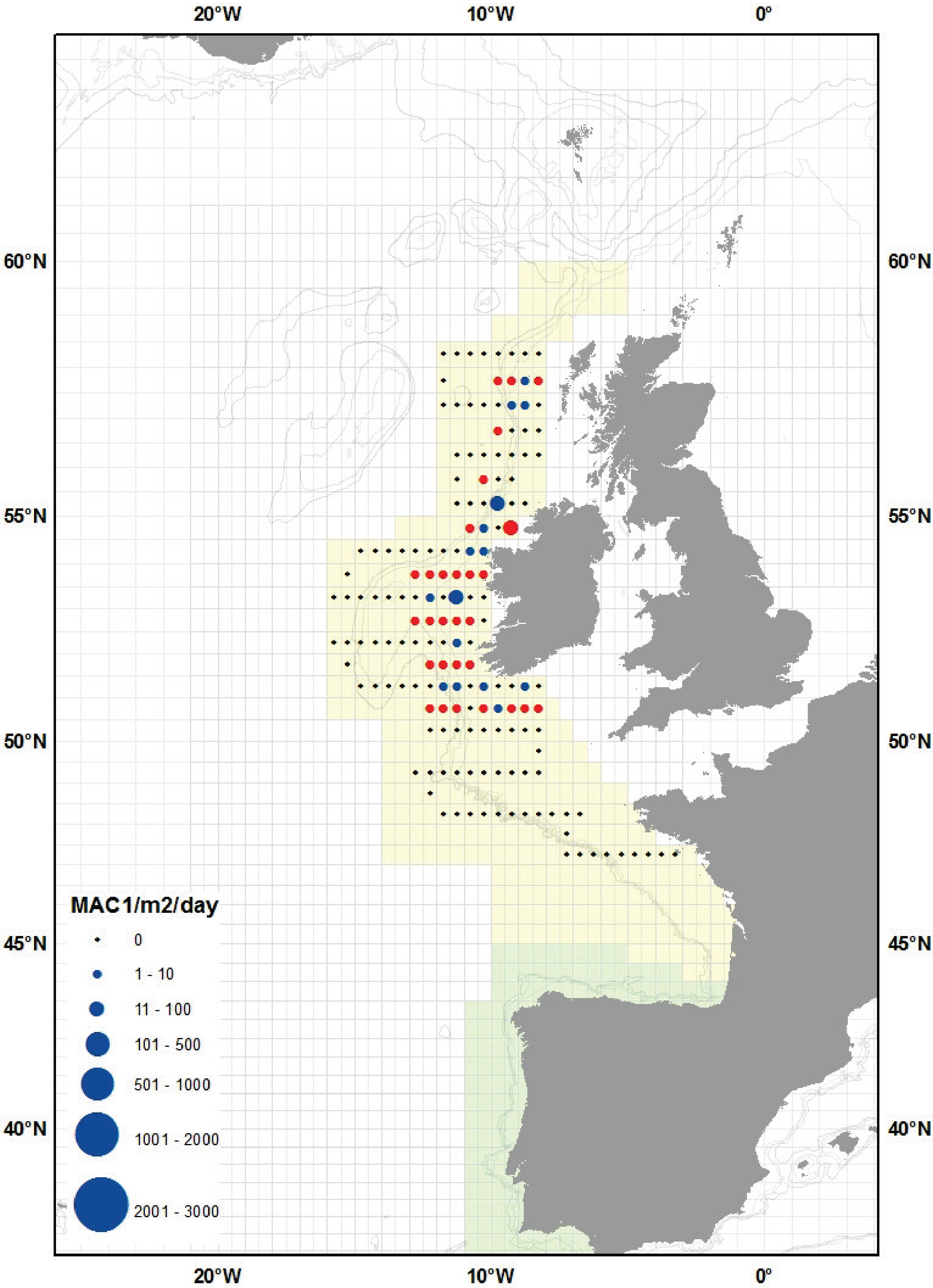

Figure 2.5.1.6: NE Atlantic Mackerel. Mackerel egg production by half rectangle for Period 6 (15th July – 31st July). Filled blue circles represent observed values, filled red circles represent interpolated values, black crosses represent observed zeroes, and red crosses interpolated zeroes.

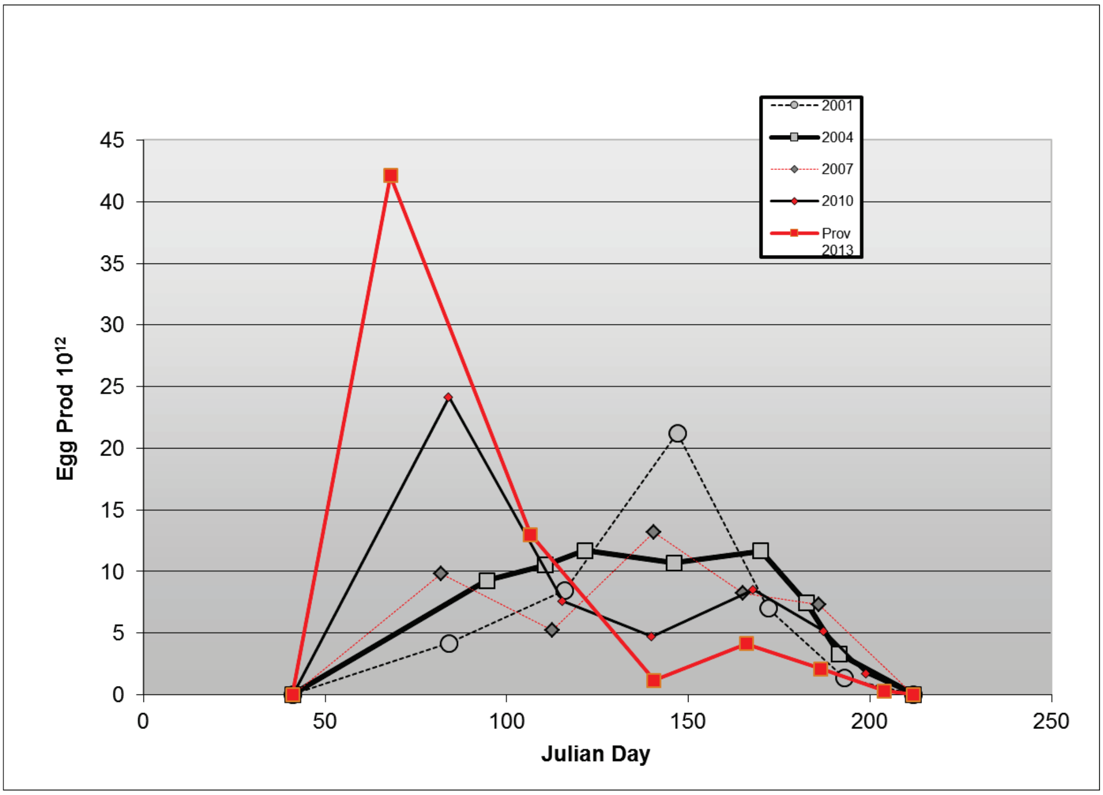

Figure 2.5.1.7: NE Atlantic Mackerel. Provisional annual egg production curve for mackerel in the western spawning component. The curves for 2001, 2004, 2007 and 2010 are included for comparison.

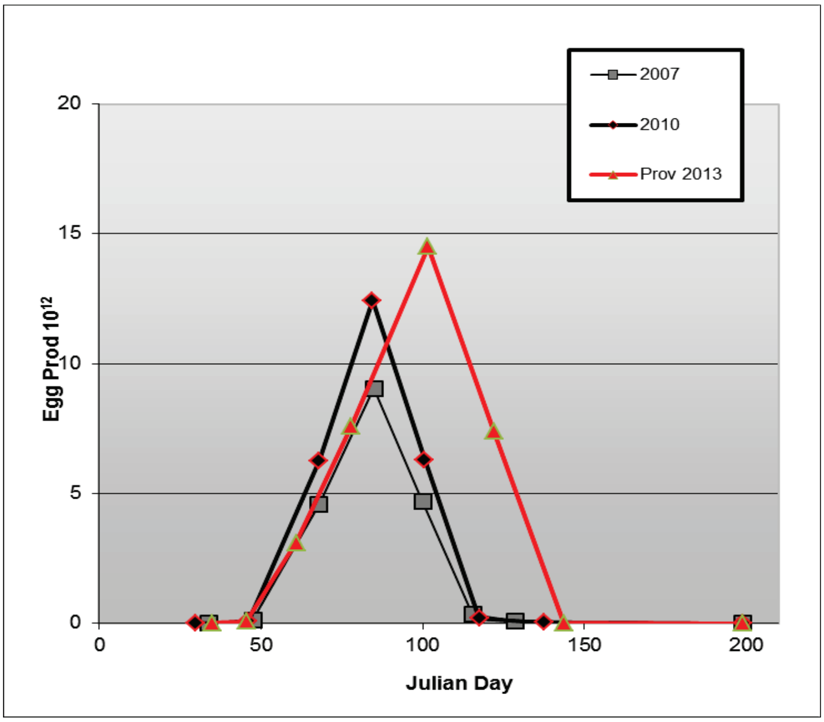

Figure 2.5.1.8: NE Atlantic Mackerel. Provisional annual egg production curve for mackerel in the southern spawning component for 2013. The curves for 2007 and 2010 are included for comparison.

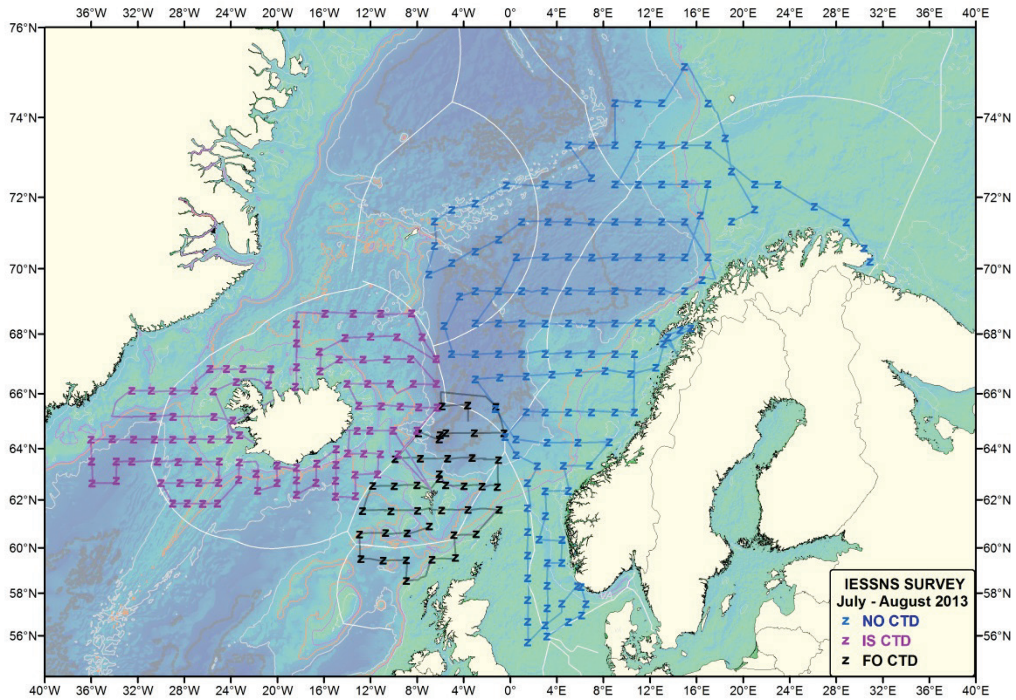

Figure 2.5.3.2.1. CTD stations (0-500 m) using SEABIRD SBE 37 (Arni Fridriksson) SEABIRD SB 25+ (Finnur Friði) and SAIV SD200 (Libas and Eros) CTD sensors and WP2 plankton net samples (0-200 m depth). These were taken systematically on every pelagic trawl station on all four vessels.

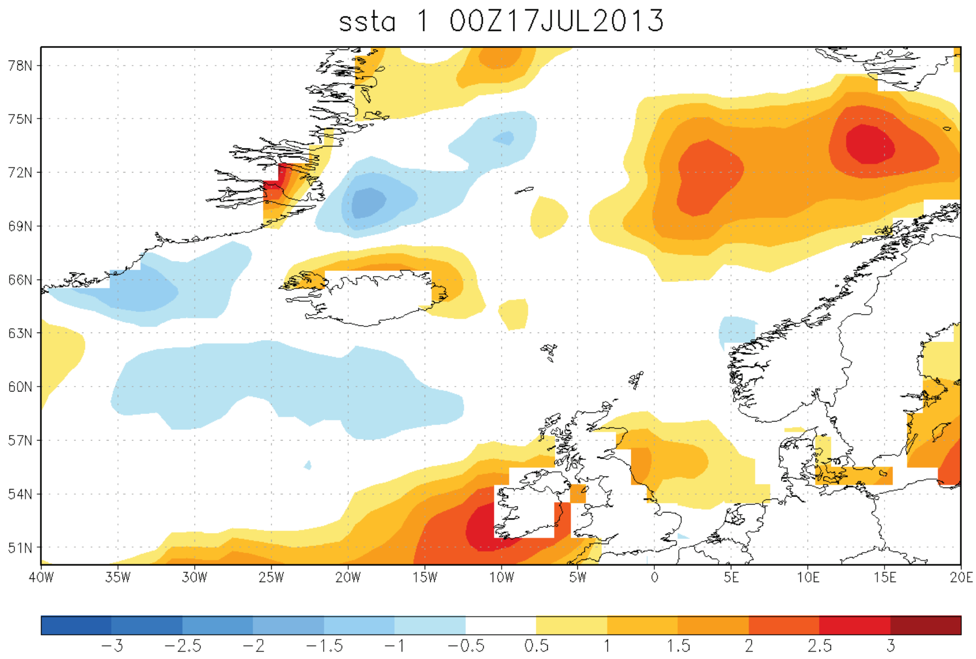

Figure 2.5.3.2.2. Sea surface temperature anomalies (°C; centered for mid July 2013) showing warm and cold conditions in comparison to a 20 year average.

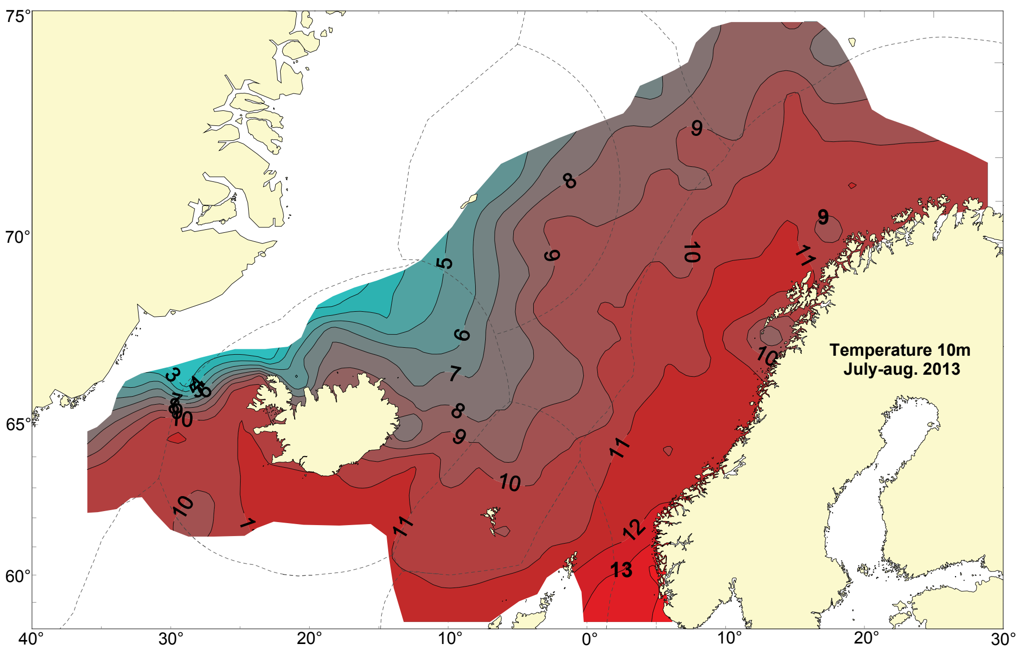

Figure 2.5.3.2.3. Temperature (°C) at 10 m depth in the Norwegian Sea and surrounding waters in July/August 2013.

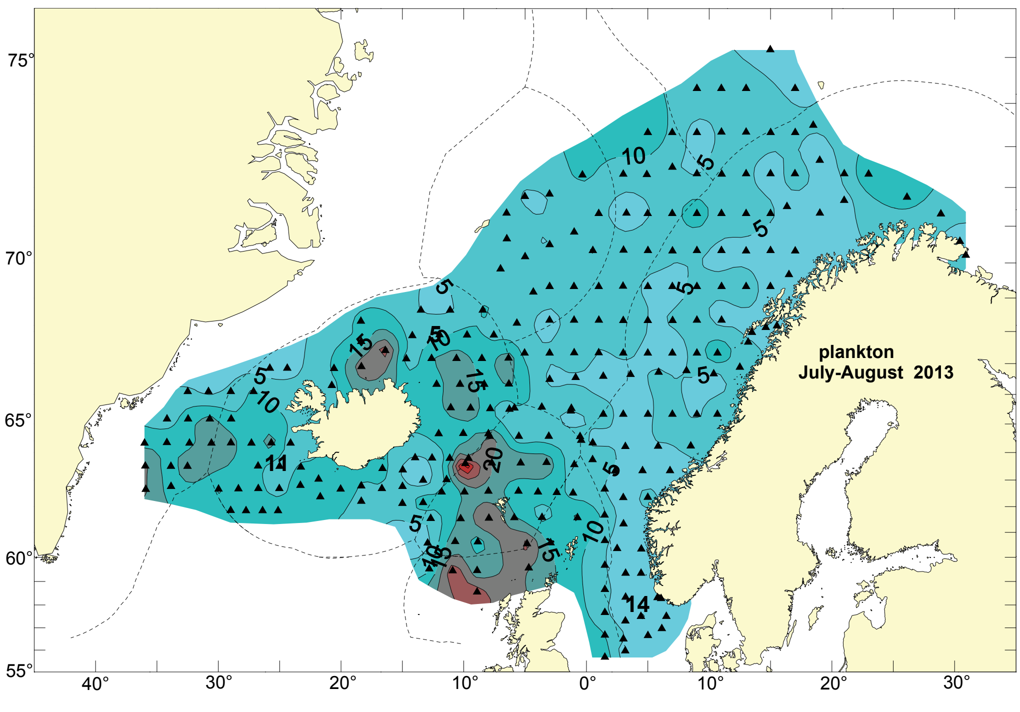

Figure 2.5.3.2.4. Zooplankton biomass (g dw/m², 0-200 m) in the Norwegian Sea and surrounding waters, 2nd of July -9th of August 2013.

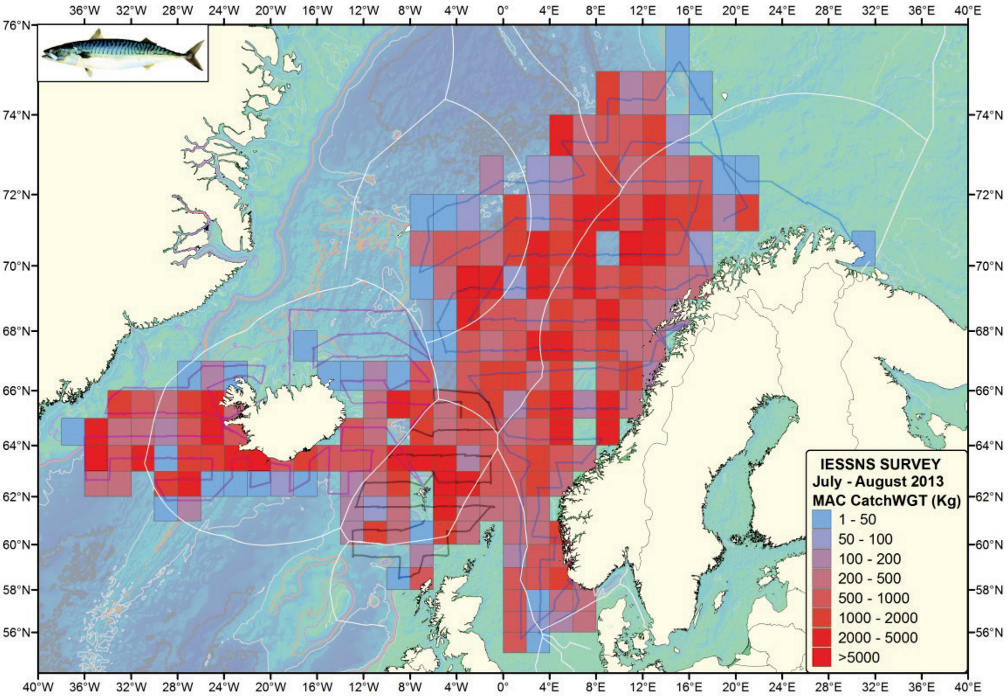

Figure 2.5.3.2.5. Catches of mackerel in kg represented in standardized rectangles. Light blue represents small catches (1-50 kg), while dark red represents catches of more than 5000 kg mackerel. Vessel tracks are shown as continuous lines.

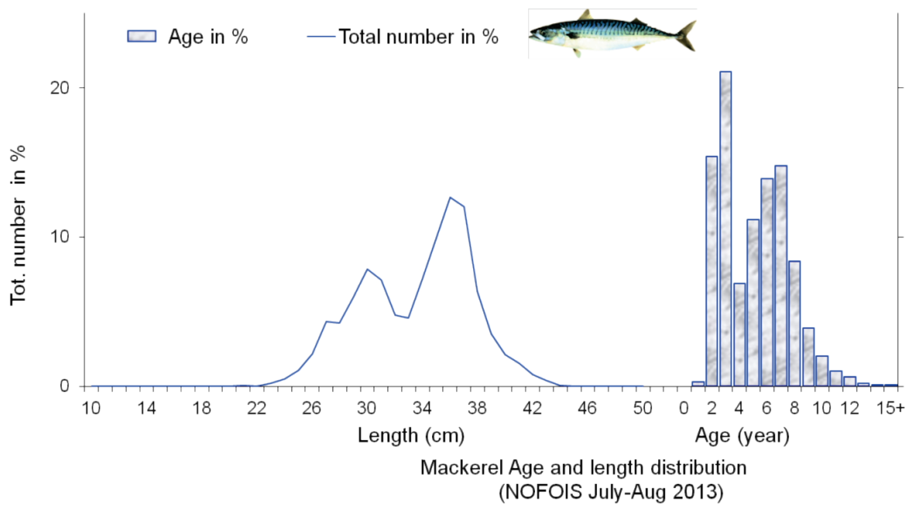

Figure 2.5.3.2.6. Age and length distribution in percent (%) of Atlantic mackerel in the Norwegian Sea and surrounding waters from 2nd of July to 9th of August 2013.

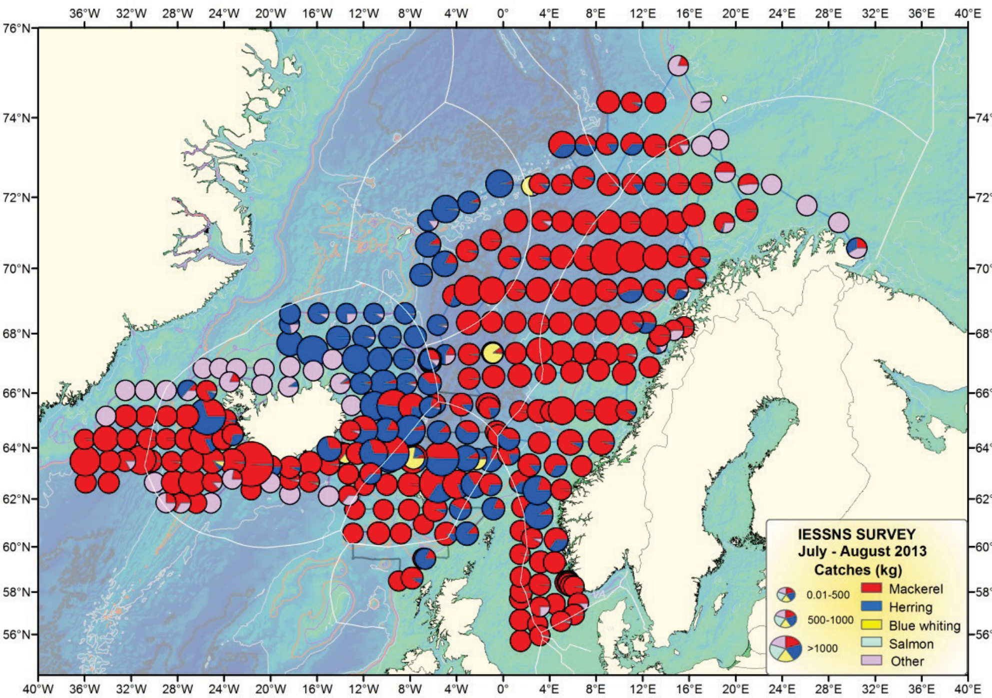

Figure 2.5.3.2.7. Distribution and spatial overlap between mackerel (red), herring (blue), blue whiting (yellow) and salmon (violet) from joint ecosystem surveys conducted onboard M/V "Libas" and M/V "Eros" (Norway), M/V "Finnur Friði" (Faroe Islands) and R/V "Arni Fridriksson" (Iceland) in the Norwegian Sea and surrounding waters between 2nd of July and 9th of August 2013. Vessel tracks are shown as continuous lines.

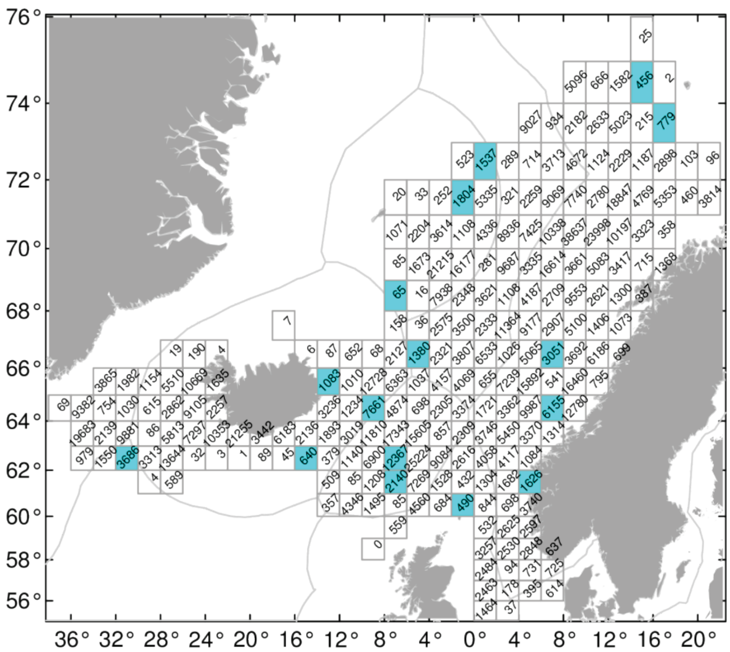

Figure 2.5.3.2.8. Mean mackerel catch index (kg/km) in 1° lat. by 2° lon. rectangles from swept area estimates in July/August 2013, where interpolated rectangles are denoted with blue shading.

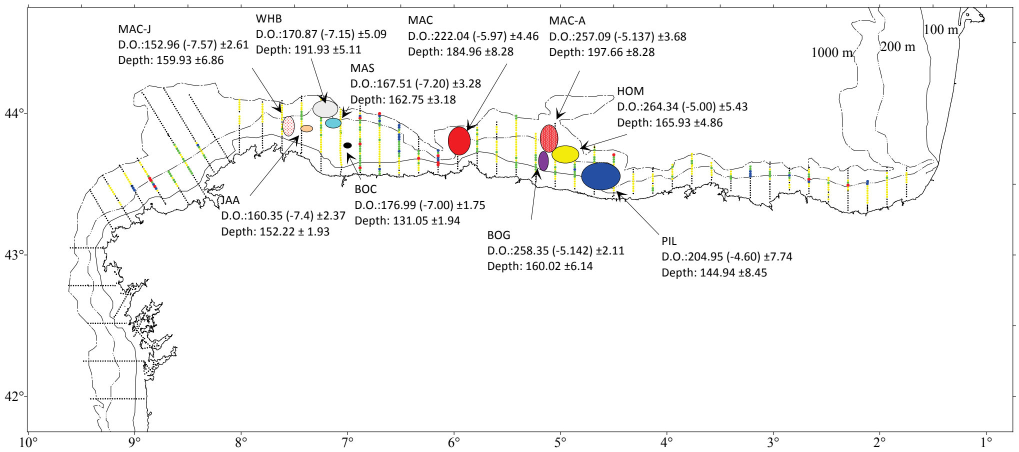

Figure 2.5.3.3.1. Spanish spring acoustic survey (PELACUS 0313). Survey track with NASC values attributed to mackerel together with the centre of gravity of the main fish species calculated as the NASC weighting average using Distance to the Origin (D.O.; expressed in nautical miles) and depth (DEPTH, expressed in meters) together with its standard deviation, and the conversion to geographical position of the distance to the origin (Lat/Lon). (WHB-blue whiting; MAC-mackerel; HOM- horse mackerel; PIL-sardine; JAA-blue jack mackerel; BOG-bogue; MAS-chub mackerel; BOC-board fish; MAC-Juvenile (<30 cm length); MAC-Adult (>30 cm length))

Figure 2.5.3.3.2. Spanish spring acoustic surveys (PELACUS) from 2001 to 2013. Top panel: total mackerel abundance (individuals x10^6, black line), and split for Age group 1 (red line) and Age group +2 (blue line); dashed lines are respectively the historical average means. Bottom panel: total biomass (mt x 10^3); dashed black line represents historical mean average.

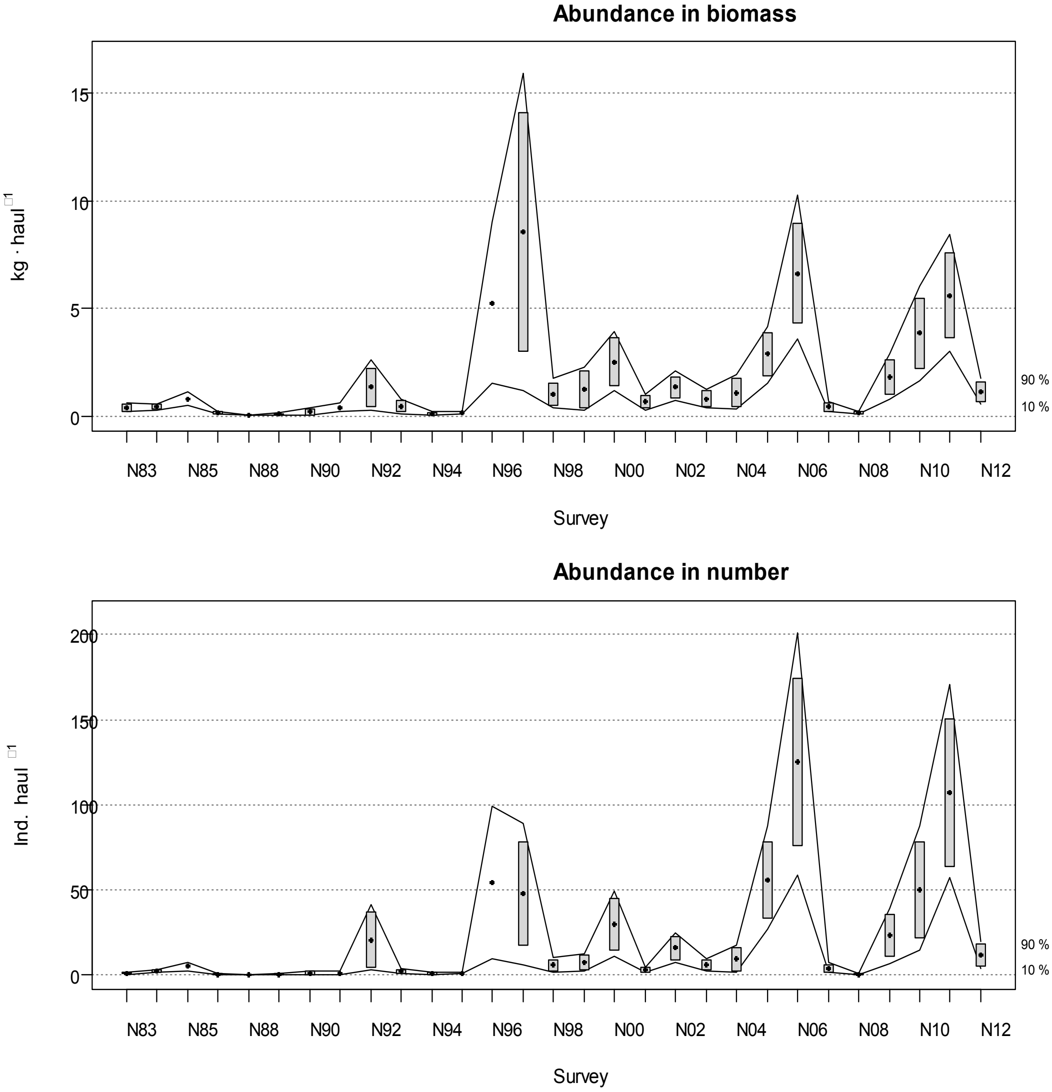

Figure 2.5.3.3.3.a. Spanish fall bottom trawl survey (DEMERSALES) from 1983 to 2012. Changes in mackerel biomass and number indices time series (1983-2012). Boxes mark parametric standard errors of the stratified abundance index. Lines mark bootstrap confidence intervals (□ = 0.80, bootstrap iterations = 1000).

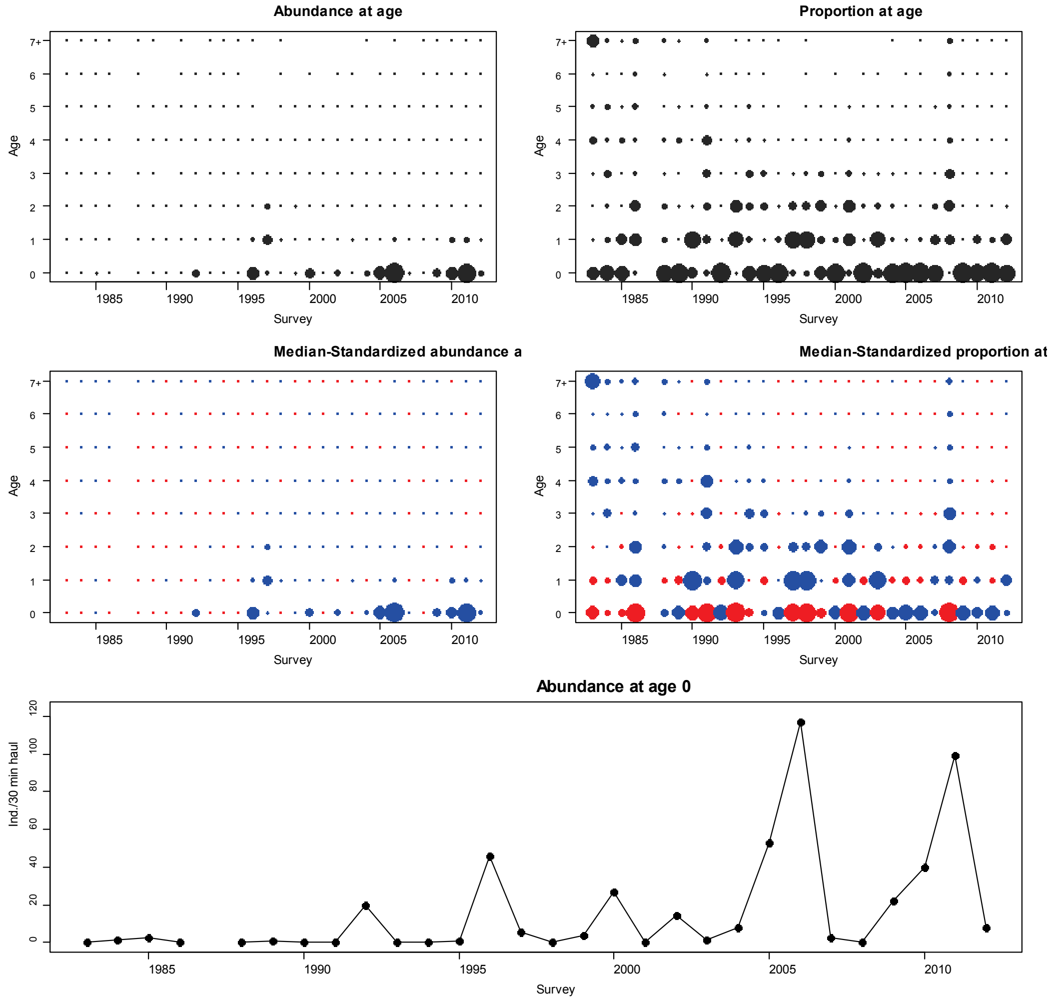

Figure 2.5.3.3.3.b. Spanish fall bottom trawl survey (DEMERSALES) from 1983 to 2012. Bubbleplot of mackerel abundances at age (0-7+), proportion at age and standardized abundances at age ((year-median years)/max(time series)) and proportion at age (No survey In 1987). (+ year with median value). Bottom graph: recruitment (age 0) time series

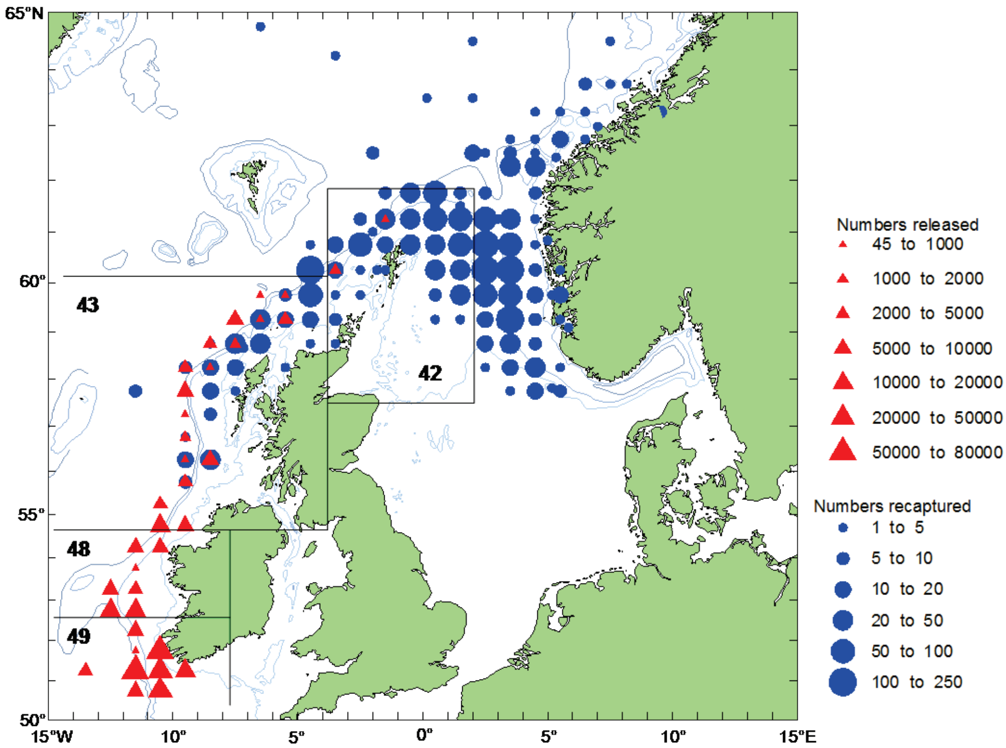

Figure 2.5.4.1. NE Atlantic Mackerel. Numbers and geographical positions of released NEA mackerel (red) and recaptured NEA mackerel (blue). Reproduced from Tenningen et al. (2011).

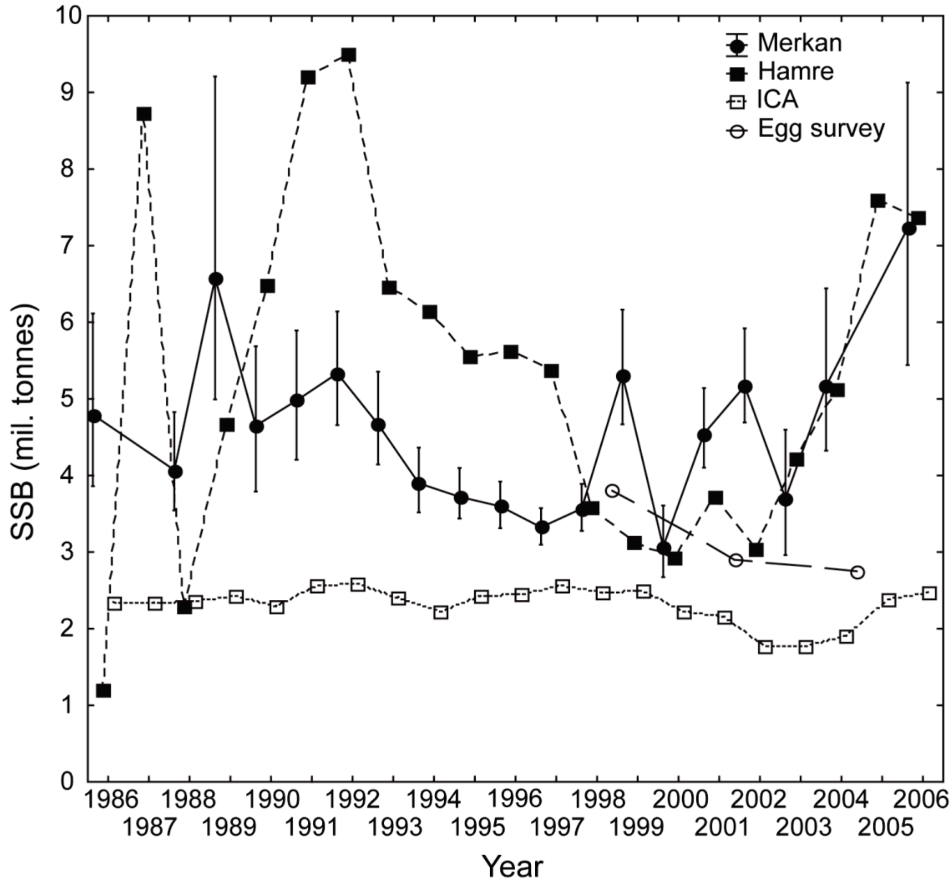

Figure 2.5.4.2. NE Atlantic Mackerel. Stock biomass estimates of 3-12 year old mackerel, 1986-2006, based on the MERKAN (solid line and filled circles) and the HAMRE (broken line and filled squares) models. The estimates are compared with the official spawning stock biomass estimates (dotted line and open squares, ICES, 2009a) and the triennial egg survey SSB estimates (dotted line and open circles, ICES, 2008). The MERKAN estimates are presented as bootstrap medians with 25th and 75th percentiles. The fluctuations in spawning stock biomass (SSB) based on tagging data is very different from that coming out of the ICES ICA-assessments, but with high uncertainty in recent years.

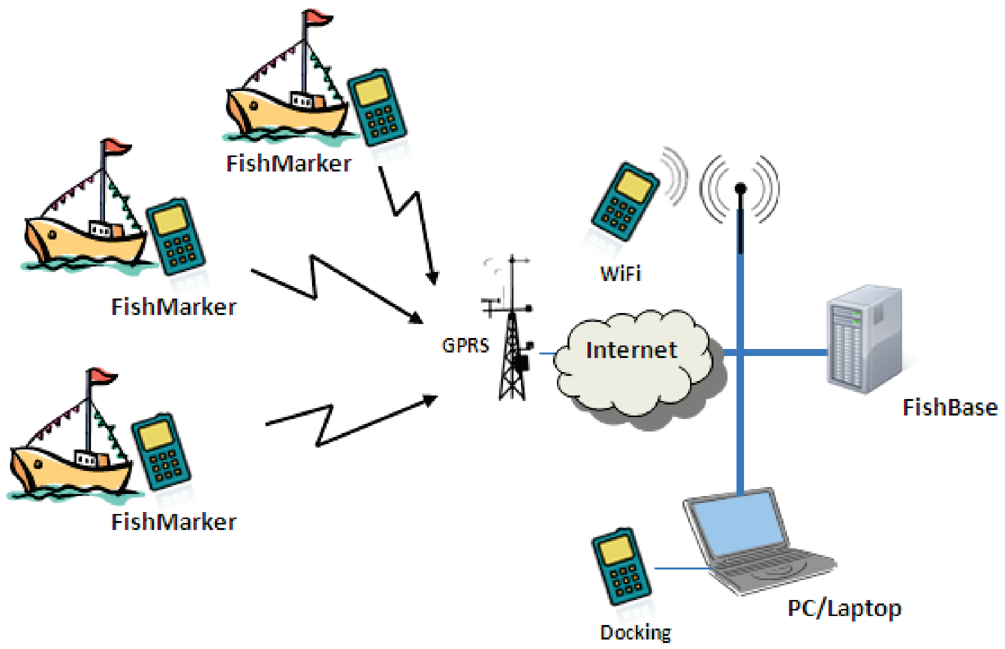

Figure 2.5.4.3. Schematic illustration of how the radio frequency identification (RFID) tagging system works.

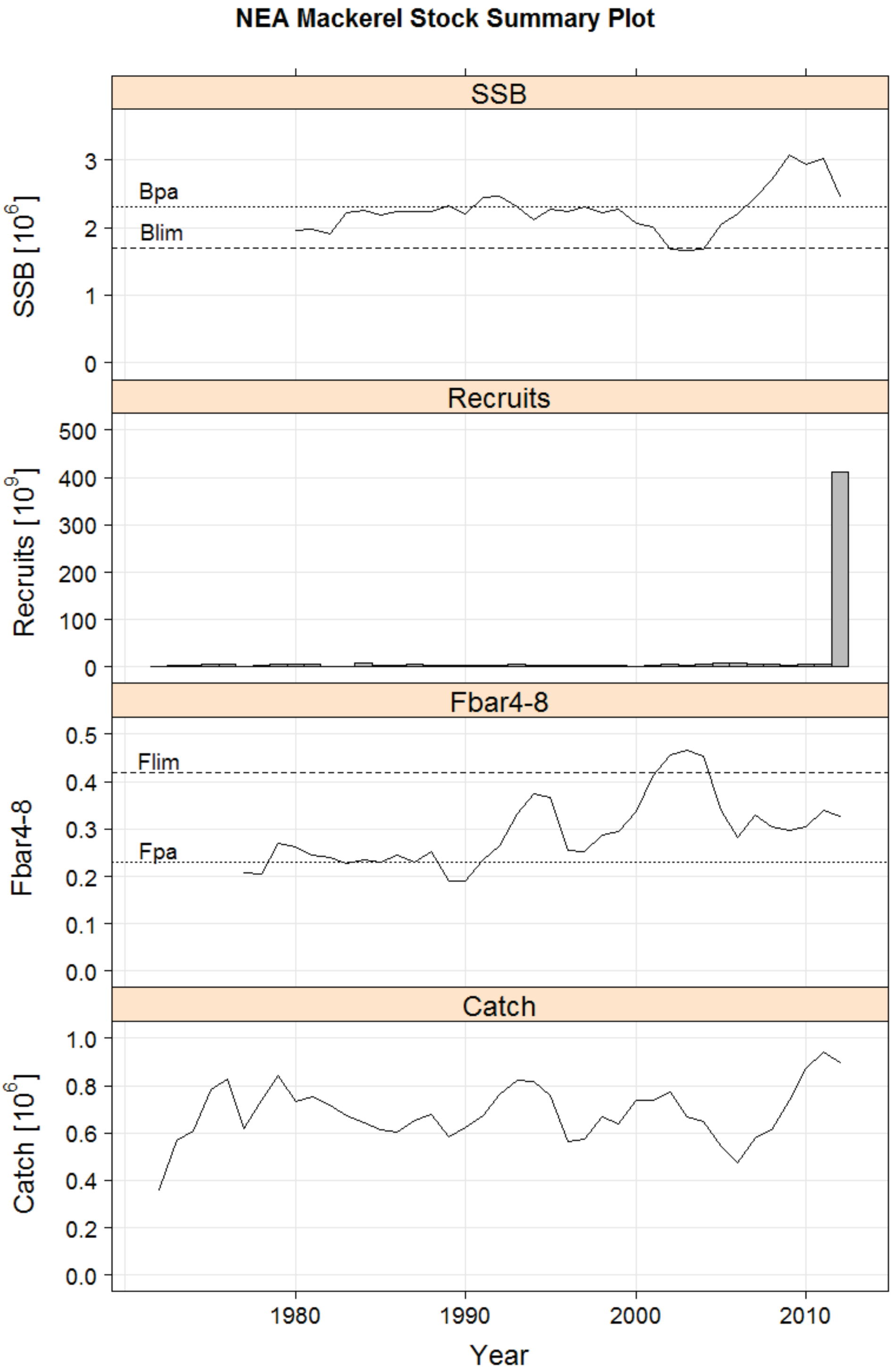

Figure 2.6.1.1. NE Atlantic Mackerel. Illustration of stock trends in NE Atlantic Mackerel from the update assessment. Summary of estimates of spawning stock biomass (1980 to 2012), recruitment from 1972-2012, Fbar4-8 from 1977 to 2012 and catches from 1972 to 2012. NB : the 2012 recruitment is not a geometric mean, but the ICA estimate

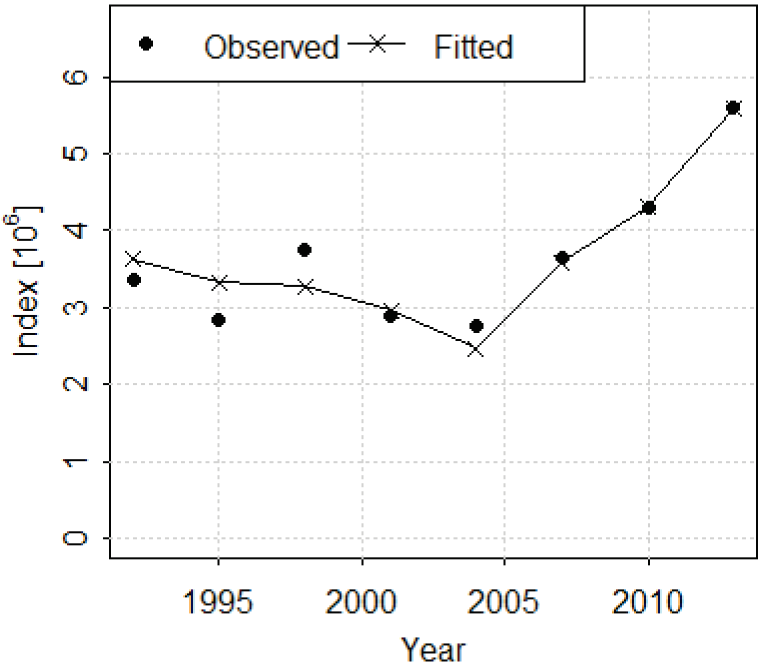

Figure 2.6.1.2. NE Atlantic mackerel. Diagnostics of the mackerel egg survey fit from the update assessment : Comparison of observed (points) and fitted (line) index value.

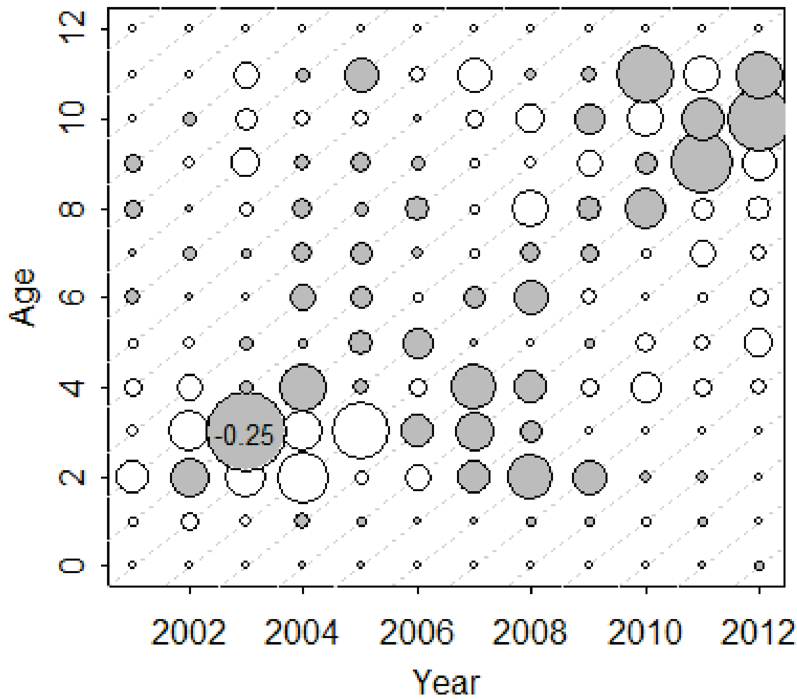

Figure 2.6.1.3. NE Atlantic mackerel. Diagnostics for the fit of catch to the 12-year separable period for the update assessment: weighted log residuals by year (age 0 and 1 down-weighted)..

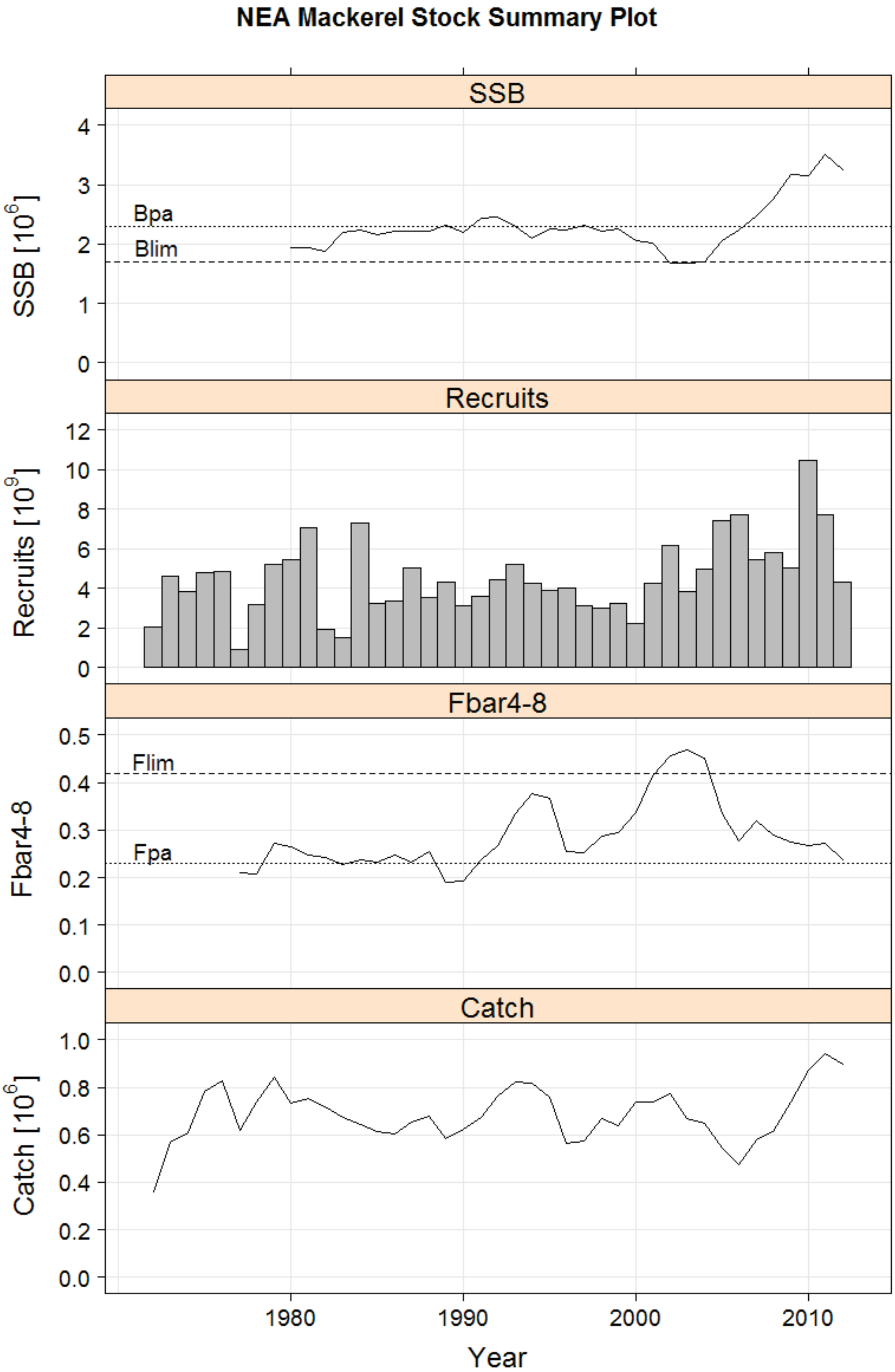

Figure 2.6.2.1. NE Atlantic Mackerel. Illustration of stock trends in NE Atlantic Mackerel from the assessment implementing a stock recruitment relationship (weighted by a lambda.SR parameter value of 0.17). Summary of estimates of spawning stock biomass (1980 to 2012), recruitment from 1972-2012, Fbar4-8 from 1977 to 2012 and catches from 1972 to 2012. NB : the 2012 recruitment is not a geometric mean, but the ICA estimate

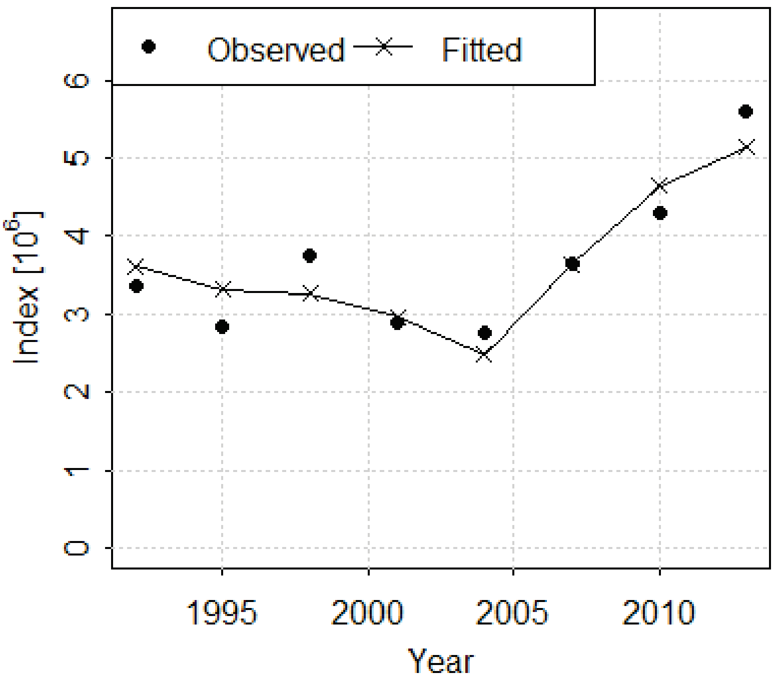

Figure 2.6.2.2. NE Atlantic Mackerel. Diagnostics of the mackerel egg survey fit from the assessment implementing a stock recruitment relationship (weighted by a lambda.SR parameter value of 0.17). Comparison of observed (points) and fitted (line) index value.

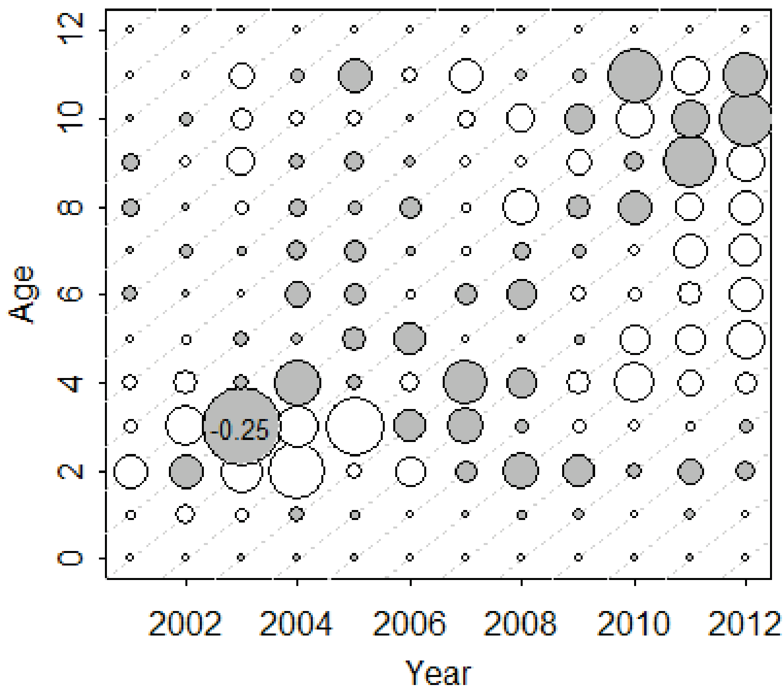

Figure 2.6.2.3. NE Atlantic Mackerel. Diagnostics for the fit of catch to the 12-year separable period for the assessment implementing a stock recruitment relationship (weighted by a lambda.SR parameter value of 0.17): weighted log residuals by year (age 0 and 1 down-weighted)..

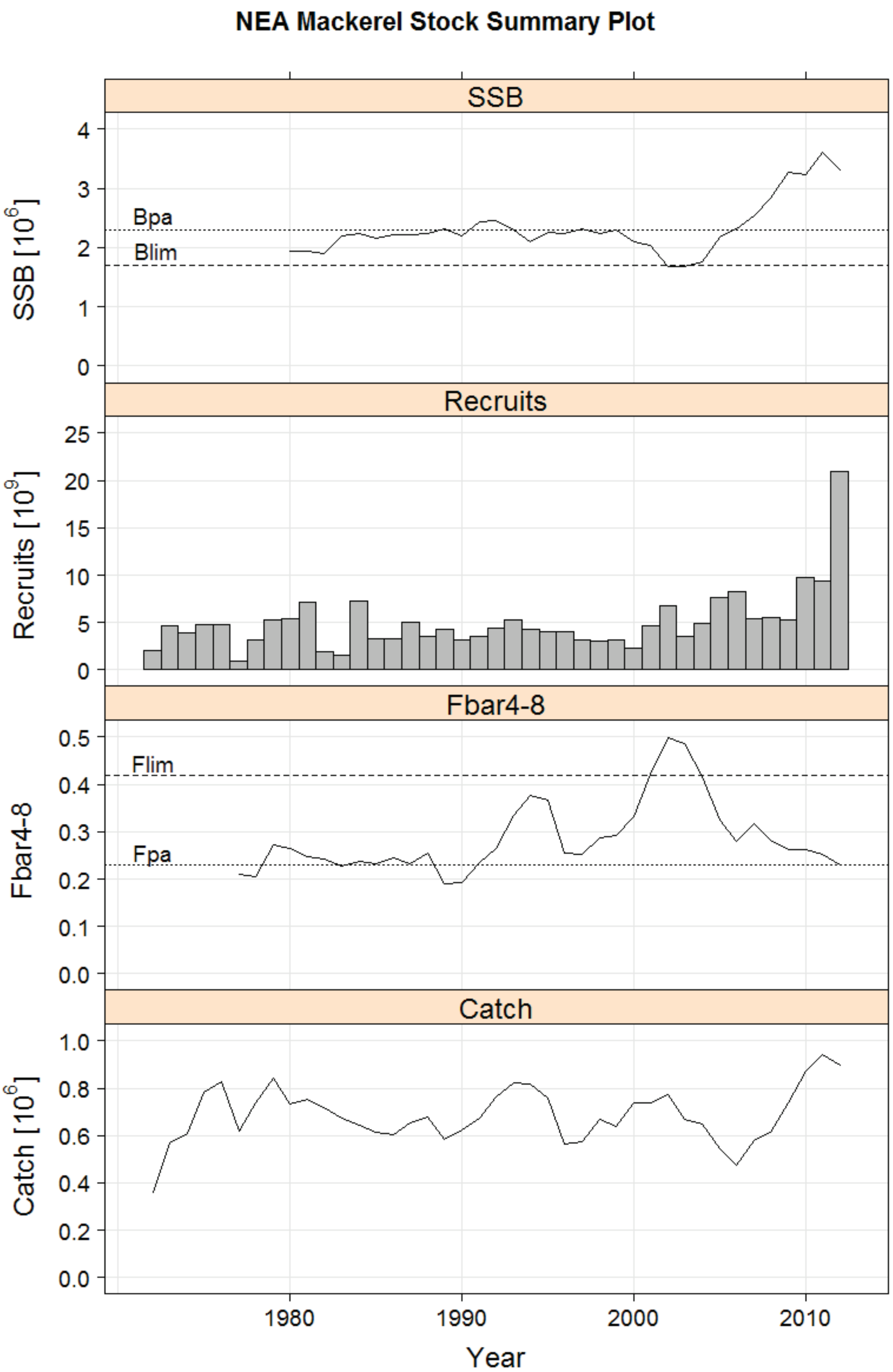

Figure 2.6.2.4. NE Atlantic Mackerel. Illustration of stock trends in NE Atlantic Mackerel from the assessment using higher weights for the catch residuals of ages 0 and 1. Summary of estimates of spawning stock biomass (1980 to 2012), recruitment from 1972-2012, Fbar4-8 from 1977 to 2012 and catches from 1972 to 2012. NB : the 2012 recruitment is not a geometric mean, but the ICA estimate

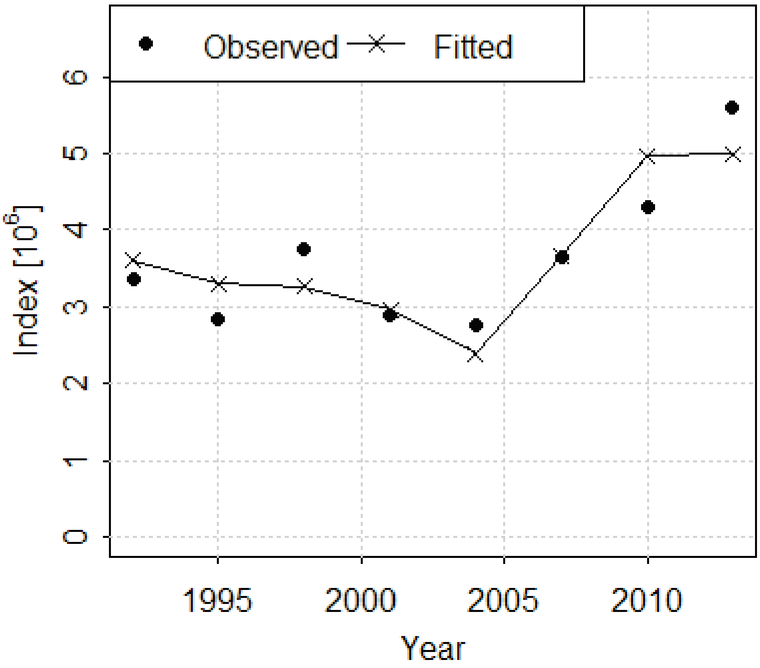

Figure 2.6.2.5. NE Atlantic Mackerel. Diagnostics of the mackerel egg survey fit from the assessment using higher weights for the catch residuals of ages 0 and 1. Comparison of observed (points) and fitted (line) index value.

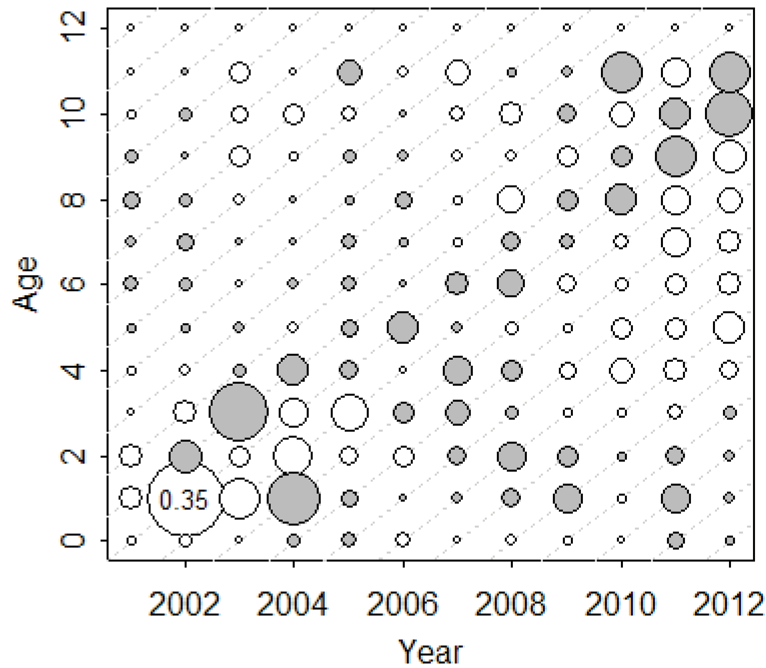

Figure 2.6.2.6. NE Atlantic Mackerel. Diagnostics for the fit of catch to the 12-year separable period for the assessment using higher weights for the catch residuals of ages 0 and 1 : weighted log residuals by year.

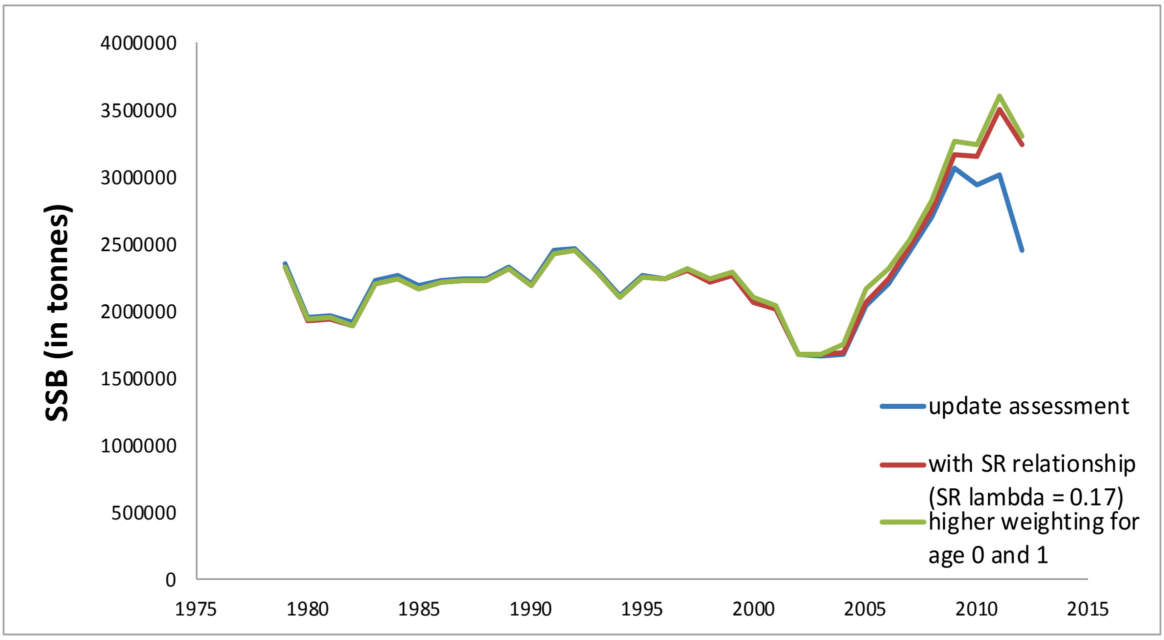

Figure 2.6.2.7. NE Atlantic Mackerel. Comparison of the historical SSB time series estimated by ICA based on three different model settings: update assessment (blue), using a stock-recruitment model (red), increasing the weighting on the residuals of the catches for age 0 and 1 (green).

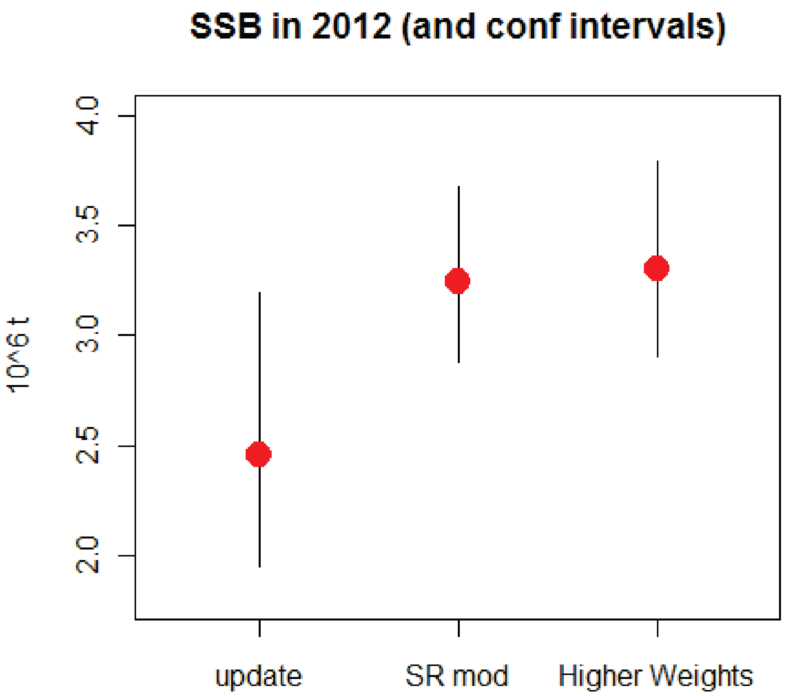

Figure 2.6.2.8. NE Atlantic Mackerel. Comparison of the estimate of SSB in the terminal year (and confidence interval) by ICA based on three different model settings: update assessment, using a stock-recruitment model, increasing the weighting on the residuals of the catches for age 0 and 1.

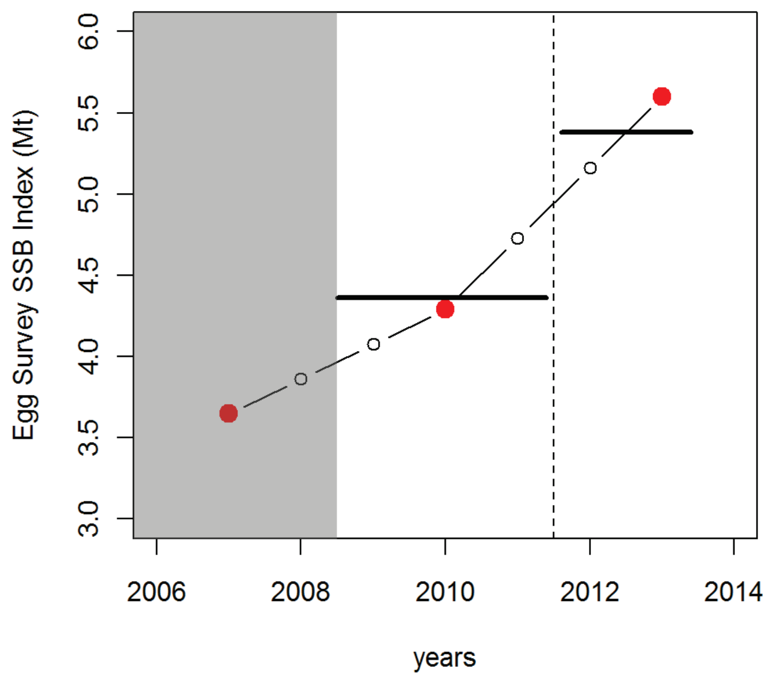

Figure 2.8.1. NE Atlantic mackerel. Calculation of the recent change in the survey index for NEA Mackerel used to compute the advised TAC. A linear interpolation (black circles) of the survey points (red points) was used to compute the ratio of the mean index value over the years 2012-2013 by the mean index value over the period 2009-2011 (two horizontal lines).

3 Horse Mackerel

3.1 Fisheries in 2012

The total international catches of horse mackerel in the North East Atlantic are shown in Table 3.1.1 and Figure 3.3.1. The southern horse mackerel stock is now assessed by ICES WGHANSA). The total catch from all areas in 2011 for the Western and North Sea stock was 194,565 tons which is 34,370 tons less than in 2011 (15% lower than in 2011). Ireland, Denmark, Scotland, France, Germany and the Netherlands have a directed trawl fishery and Norway a directed purse seine fishery for horse mackerel. Spain has directed and mixed trawl and purse seine fisheries. In earlier years most of the catches were used for meal and oil while in later years most of the catches have been used for human consumption.

The quarterly catches of North Sea and western horse mackerel by Division and Subdivision in 2011 are given in Table 3.1.2 and the distribution of the fisheries are given in Figure 3.1.1.a–d. The figures are based on data provided by Denmark, Germany, Ireland, Netherlands, Norway, Scotland, England + Wales and Spain representing 94% of the total catches. The distribution of the fishery is similar to the later years.

The Dutch and German fleets operated mainly west of the Channel, in the Channel area, north and west of Ireland and in the southern North Sea. Ireland fished mainly north and west of Ireland and Norway in the north eastern part of the North Sea. The Spanish fleet operated mainly in their respective waters. Lithuania reported catches of horse mackerel for the three years 2006-2008, but no catches were reported since 2009.

First quarter: 67,412 tons. As usual the fishery was mainly carried out west of Scotland and west and south of Ireland, in the Channel and along the Spanish coast (Figure 3.1.1.a).

Second quarter: 37,868 tons. As usual, catches were significantly lower than in the first quarter as the second quarter is the main spawning period. Most of the catches were taken south of Ireland, along the Spanish coast, in the south eastern part of the North Sea and in the Channel (Figure 3.1.1.b).

Third quarter: 15,235 tons. Most of the catches were taken in Spanish waters, west and south of Ireland and in the south part of the North Sea. Also some smaller catches were reported from the Shetland area and from the northern part of the North Sea (Figure 3.1.1.c).

Fourth quarter: This is the fishing season with most of the catches (74,049 tons). The catches were distributed in four main areas (Figure 3.1.1.d):

- Spanish waters,
- Northern Irish waters and West and north of Scotland
- northern-central part of the North Sea
- the Channel

3.2 Stock Units

For many years the Working Group has considered the horse mackerel in the north east Atlantic as separated into three stocks: the North Sea, the Southern and the

Western stocks (ICES 1990/Assess: 24, ICES 1991/Assess: 22). For further information see Stock Annex Western Horse Mackerel. The boundaries for the different stocks are given in Figure 3.2.1.

3.3 Allocation of Catches to Stocks

The distribution areas for the three stocks are given in the Stock Annex Western Horse Mackerel. The catches in 2011 were allocated to the three stocks as follows:

Western stock: 3 and 4 quarter: Divisions IIIa and IVa. 1-4 quarter: IIa, Vb, VIa, VIIa–c,e–k and VIIIa-e.

North Sea stock: 1-2 quarter: Divisions IIIa and IVa. 1-4 quarter: IVb,c and VIId.

Southern stock: Division IXa. All catches from these areas were allocated to the southern stock. This stock is now dealt with by another working group (ICES WGHANSA).

The catches by stock are given in Table 3.1.1 and Figure 3.3.1. The catches by stock and countries for the period 1997-2012 are given in Table 3.3.2-3.3.4.

In 2012 some small catches were reported from Divisions VIb (68.1 tons) and IIIc (170.5 tons) which were no allocated in any stock.

3.4 Estimates of discards

Over the years only Netherlands has provided data on discards and in some few years also Germany has provided such data. For 2012 the Netherlands, Germany, Ireland and Spain provided such data. Their catches represented about 70% of the total catch of western horse mackerel. However, based on these data it is impossible to estimate the total discard rate in the horse mackerel fishery (see section 1.3.3), since the discard rates reported are quite different. Therefore the amounts of discards given in Table 3.1.1 are not representative for the total fishery.

3.5 *Trachurus* Species Mixing

Three species of genus *Trachurus*: *T. trachurus*, *T. mediterraneus* and *T. picturatus* are found together and are commercially exploited in NE Atlantic waters. Following the Working Group recommendation (ICES 2002/ACFM: 06) special care was taken to ensure that catch and length distributions and numbers at age of *T. trachurus* supplied to the Working Group did not include *T. mediterraneus* and/or *T. picturatus*.

T. mediterraneus fishery takes mainly place in the eastern part of ICES Division VIIIc. There is not a clear trend in *T. mediterraneus* catches in this area but catches have been low in recent years (Table 3.5.1). Information of *T. picturatus* fishery is available in the WGHANSA Report (Working Group on Horse Mackerel, Anchovy and Sardine).

Taking into account that the assessment is only made for *T. trachurus*, the Working Group recommends that the TACs and any other management regulations which might be established in the future should be related only to *T. trachurus* and not to Trachurus spp. More information is needed about the *Trachurus spp*. before the fishery and the stock can be evaluated.

3.6 Length Distribution by Fleet and by Country:

Ireland, Germany, Netherlands, Norway, and Spain provided length distribution for their catches in 2011. The length distributions given by these countries covered approximately 71% of the total landings of the Western and North Sea horse mackerel catches and are shown in Table 3.6.1.

Table 3.1.1 HORSE MACKEREL general. Catches (t) by Sub-area. Data as submitted by Working Group members. Data of limited discard information are only available for some years.

Subarea	1979	1980	1981	1982	1983	1984	1985
II	2	-	+	-	412	23	79
IV + IIIa	1,412	2,151	7,245	2,788	4,420	25,987	24,238
VI	7,791	8,724	11,134	6,283	24,881	31,716	33,025
VII	43,525	45,697	34,749	33,478	40,526	42,952	39,034
VIII	47,155	37,495	40,073	22,683	28,223	25,629	27,740
IX	37,619	36,903	35,873	39,726	48,733	23,178	20,237
Total	137,504	130,970	129,074	104,958	147,195	149,485	144,353

Subarea	1986	1987	1988	1989	1990	1991	1992
II	214	3,311	6,818	4,809	11,414	4,487	13,457
IV + IIIa	20,746	20,895	62,892	112,047	145,062	77,994	113,141
VI	20,455	35,157	45,842	34,870	20,904	34,455	40,921
VII	77,628	100,734	90,253	138,890	192,196	201,326	188,135
VIII	43,405	37,703	34,177	38,686	46,302	49,426	54,186
IX	31,159	24,540	29,763	29,231	24,023	34,992	27,858
	193,607	222,340	269,745	358,533	439,901	402,680	437,698

Subarea	1993	1994	1995	1996	1997	1998	1999
II	3,168	759	13,133	3,366	2,617	2,538	2,557
IV + IIIa	140,383	112,580	98,745	27,782	81,198	31,295	58,746
VI	53,822	69,616	83,595	81,259	40,145	35,073	40,381
VII	221,120	200,256	330,705	279,109	326,415	250,656	186,604
VIII	53,753	35,500	28,709	48,269	40,806	38,562	47,012
IX	31,521	28,442	25,147	20,400	29,491	41,574	27,733
Total	503,767	447,153	580,034	460,185	520,672	399,698	363,033

Subarea	2000	2001	2002	2003	2004	2005	2006
II	1,169	60	1,324	24	47	176	30
IV + IIIa	31,583	19,839	49,691	34,226	30,540	40,564	38,911
VI	20,657	24,636	14,190	23,254	21,929	22,055	15,751
VII	137,716	138,790	97,906	123,046	116,139	107,475	101,912
VIII	54,211	75,120	54,560	41,711	24,125	41,495	34,122
IX	26,160	24,912	23,665	19,570	23,581	23,111	24,557
Total	272,496	283,357	241,335	241,831	216,361	234,876	215,283

Subarea	2007	2008	2009	2010	2011	2012[1]
II	366	572	1,847	1,656	648	66
IV + IIIa	16,407	15,377	78,591	13,670	25,183	5,265
VI	26,279	25,902	17,776	22,612	39,528	44,975
VII	93,132	98,746	89,563	145,320	127,903	123,579
VIII	28,387	33,892	33,355	43,227	35,675	17,402
IX	23,423	23,596	26,496	27,217	22575	25316
Total	187,994	198,085	247,628	253,702	251512	216603

[1]Preliminary. * Southern Horse Mackerel is assessed by ICES WGHANSA since 2011

Table 3.1.2 HORSE MACKEREL Western and North Sea Stock combined.Quarterly catches (1000 t) by Division and Subdivision in 2012.

Division	1Q	2Q	3Q	4Q	TOTAL
IIa+Vb	0	0	+	+	66
III	0	0	+	+	9
IVa	260	95	61	3251	3667
IVbc	+	530	168	891	1590
VIId	647	2592	928	15314	19481
VIa,b	14873	+	1806	28280	44971
VIIa–c,e–k	47514	26765	8685	24222	107186
VIIIa,b,d,e	1177	2502	978	394	5051
VIIIc	2940	5371	2576	1657	12544
Sum	67412	37868	15235	74049	194564

+ less than 50 t

Table 3.3.1 HORSE MACKEREL general. Landings and discards (t) by year and Division, for the North Sea, Western, and Southern horse mackerel stocks. (Data submitted by Working Group members.)

Year	IIIa	IVa	IVb,c	Discards	VIId	North Sea Stock	IIa Vb	IIIa	IVa	VIa,b	VIIa-c, e-k	VIIIa,b,d,e	VIIIc	Disc	Western Stock	Western + NS Stock	Southern Stock (IXa)	All stocks
1982	2,788[1]		-		1,247	4,035	-		-	6,283	32,231	3,073	19,610	-	61,197	65,232	39,726	104,958
1983	4,420[1]		-		3,600	8,020	412		-	24,881	36,926	2,643	25,580	-	90,442	98,462	48,733	147,195
1984	25,893[1]		-		3,585	29,478	23		94	31,716	38,782	2,510	23,119	500	96,744	126,222	23,178	149,400
1985	-		22,897		2,715	26,750	79		203	33,025	35,296	4,448	23,292	7,500	103,843	130,593	20,237	150,830
1986	-		19,496		4,756	24,648	214		776	20,343	72,761	3,071	40,334	8,500	145,999	170,647	31,159	201,806
1987	1,138		9,477		1,721	11,634	3,311		11,185	35,197	99,942	7,605	30,098	-	187,338	198,972	24,540	223,512
1988	396		18,290		3,120	23,671	6,818		42,174	45,842	81,978	7,548	26,629	3,740	214,729	238,400	29,763	268,163
1989	436		25,830		6,522	33,265	4,809		85304[2]	34,870	131,218	11,516	27,170	1,150	296,037	329,302	29,231	358,533
1990	2,261		17,437		1,325	18,762	11,414	14,878	112753[2]	20,794	182,580	21,120	25,182	9,930	398,645	417,407	24,023	441,430
1991	913		11,400		600	12,000	4,487	2,725	63869[2]	34,415	196,926	25,693	23,733	5,440	357,288	369,288	34,992	404,280
1992			13,955	400	688	15,043	13,457	2,374	101,752	40,881	180,937	29,329	24,243	1,820	394,793	409,836	27,858	437,694
1993			3,895	930	8,792	13,617	3,168	850	134,908	53,782	204,318	27,519	25,483	8,600	458,628	472,245	31,521	503,766
1994			2,496	630	2,503	5,689	759	2,492	106,911	69,546	194,188	11,044	24,147	3,935	413,022	418,711	28,442	447,153
1995	112		7,948	30	8,666	16,756	13,133	128	90,527	83,486	320,102	1,175	27,534	2,046	538,131	554,887	25,147	580,034
1996	1,657		7,558	212	9,416	18,843	3,366		18,356	81,259	252,823	23,978	24,290	16,870	420,942	439,785	20,400	460,185
1997			14,078	10	5,452	19,540	2,617	2,037	65073[3]	40,145	318,101	11,677	29,129	2,921	471,700	491,240	29,491	520,731
1998	3,693		10,530	83	16,194	30,500	2540[4]		17,011	35,043	232,451	15,662	22,906	830	326,443	356,943	41,574	398,517
1999			9,335		27,889	37,224	2557[5]	2,095	47,316	40,381	158,715	22,824	24,188		298,076	335,300	27,733	363,033
2000			25,954		22,471	48,425	1169[6]	1,105	4,524	20,657	115,245	32,227	21,984		196,911	245,336	26,160	271,496
2001	85	69	8,157		38,114	46,356	60	72	11,456	24,636	100,676	54,293	20,828		212,090	258,446	24,912	283,357
2002			12,636	20	10,723	23,379	1,324	179	36,855	14,190	86,878	32,450	22,110	305	194,292	217,671	23,665	241,336
2003	48	623	10,309		21,098	32,078	24	1,974	21,272	23,254	101,948	21,732	19,979		190,183	222,261	19,570	241,831
2004	351		18,348		16,455	35,154	47		11,841	21,929	98,984	8,353	15,772	701	157,627	192,781	23,581	216,361
2005	357		13,892	62	15,460	29,711	176		26,315	22,054	91,431	26,483	14,775	760	181,994	211,705	23,111	234,816
2006	1,099	2,661	7,998	78	23,790	35,626	30		27,152	15,722	77,970	20,651	13,470	99	155,094	190,720	24,557	215,277
2007	63	2,056	9,118	139	29,788	41,164	366	110	4,940	26,279	63,223	14,428	13,960	102	123,408	164,572	23,423	187,994
2008	27	1,003	2,330		31,389	34,749	572[7]	3	12,014	25,902	67,325	14,537	19,345	43	139,741	174,490	23,596	198,085
2009	38	72	18,711	1,036	24,366	44,223	1,847	-	58,738	17,775	65,122	12,452	20,903	81	176,918	221,141	26,496	247,637
2010	+	100	1,965	2	20,188	22,255	1,627	88	11,516	22,641	114,483	2,042	37,505	15,366	205,268	227,004	27,217	254,221
2011	0.2		10,458		18,886	29,344	648	1	14,724	39,298	103,156	2,303	32,943	6,522	199,593	228,937	22,575	251,512
2012	0.2	355	1,588		19,480	21,423	66	9	3,312	44,975	104,098	5051	12351	3,280	173,142	194,565	25316	219881

1Divisions IIIa and IVb,c combined. X Southern Horse Mackerel is assessed by ICES WGHANSA since 2011 2Norwegian catches in IVb included in Western horse mackerel.
3 Includes Norwegian catches in IVb (1,426 t). 4Includes 1,937 t from Vb, 5Includes 132 t from Vb. 6Includes 250 t from Vb. 7 all fom Vb.

Table 3.3.2 National catches of the Western Horse mackerel stock.

Country	1997	1998	1999	2000	2001	2002	2003	2004	2005
Belgium	18	-	-	-	19	-	-	+	+
Denmark	62,897	29,542	22,663	13,084	6,108	10,152	11739	11,480	1,021
Estonia	78	22	-	-	-	-	-	-	-
Faroe Islands	1,095	216	905	824	-	699	59	3,847	3,695
France	39,188	24,267	25,141	20,457	15,145	18,951	10,383	8,060	10,690
Germany, Fed.Rep.	28,533	27,872	17,629	13,348	11,493	12,614	15,826	17,830	16,734
Ireland	74,250	70,811	57,956	55,300	51,874	36,483	35,855	26,431	35,361
Lithuania	-	-	-	-	-	-	-	-	-
Netherlands	82,885	92,535	75,333	57,971	73,439	42,019	47,327	40987	43,445
Norway	45,058	13,363	46,410	2,087	7,956	36,689	20,315	10751	25,113
Russia	554	345	121	80	16	3	-	5	-
Spain	31,087	14,882	25,123	22,669	23,053	23,214	24,588	16,272	16,636
Sweden	1,761	10	1,952	1,101	68	575	1,074	568	148
UK (Engl. + Wales)	19,778	12,162	9,257	1,555	7,096	5,971	4,440	4,617	3,560
UK (N. Ireland)	-	1,158	-	-	-	-	-	-	426
UK (Scotland)	32,865	18,283	11,197	7,230	8,029	2,907	672	1,523	142
Unallocated	48,732	20,145	4,389	823	7,794	3,710	17,905	15,256	24,263
Discard	2,921	830	-	382	-	305	-	701	760
Total	471,700	326,443	298,076	196,911	212,090	194,292	190,183	158328	181,994

Country	2006	2007	2008	2009	2010	2011	2012
Belgium	-	-	-	-	19	2	0.2
Denmark	8,353	7,617	5,261	6,009	5,941	6,109	4,002
Estonia	-	-	-	-	-	-	
Faroe Islands	1,205	478	841	-	374	349	-
France	11,034	12,748	12,626	-	260	8,271	1,795
Germany, Fed.Rep.	10,863	5,784	11,708	15,121	17,688	21,114	17,063
Ireland	26,779	30,091	35,612	40,754	44,488	38,464	45,242
Lithuania	6,829	5,467	5,548	-	-	-	-
Netherlands	37,130	29,083	43,648	39,451	61,504	55,692	66,396
Norway	27,114	4,182	1,223	59,764	11,978	13,755	3,251
Russia	-	-	-	-	-	-	
Spain	13,878	14,257	19,851	21,077	38,744	34,581	13,560
Sweden	-	76	9	258	2	90	-
UK (Engl. + Wales)	3,583	5,482	3,365	6,482	12,714	11,716	12,122
UK (N. Ireland)	224	-	-	-	-	-	-
UK (Scotland)	469	778	1,077	1,413	2,348	2,928	1,335
Unallocated	7,534	7,263	2,294	-7,010	7,237	-	5,095
Discard	99	102	43	81	14,846	6,522	3,280
Total	155,094	123,408	143,106	183,400	218,143	199,593	173,141

[1]Preliminary

Table 3.3.3. National catches of the North Sea Horse mackerel stock.

Country	1997	1998	1999	2000	2001	2002	2003	2004	2005
Belgium	-	19	21	19	19	30	5	4	6
Denmark	180	1,481	3,377	7,855	17,316	2,310	2,902	8,738	3,987
Faroe Islands	-	-	135	-	-	-	-	-	-
France	3,246	2,399	-	-	1,696	1,246	2,326	2,530	5,236
Germany, Fed.Rep.	7,847	5,844	5,920	3,728	968	3,267	2,936	4,912	2,248
Ireland	-	2,861	27	130	338	-	-	1	-
Lithuania	-	10,711	-	-	-	-	-	-	-
Netherlands	36,855	-	8,117	7,987	13,867	15,187	24,118	26,302	25,579
Norway	-	-	238	-	36	-	-	-	-
Sweden	-	3,401	5	40	46	14	-	97	91
UK (Engl. + Wales)	269	907	11	1,585	3,333	2,323	1,965	1,552	3,859
UK (Scotland)	29	-	-	421	-	-	-	-	-
Unallocated	-28,896	2,794	19,373	26,660	8,737	-1,018	-2,174	-8,982	-11,358
Discard	10	83	-	-	-	20	-	-	62
Total	19,540	30,500	37,224	48,425	46,356	23,379	32,078	35,154	29,711

Country	2006	2007	2008	2009	2010	2011	2012[1]
Belgium	4	6	3	5	17	26	46
Denmark	1,341	255	57	89	15	142	1514
Faroe Islands	-	-	-	-	-	-	0
France	4,380	5,349	2,246	-	813	273	1,047
Germany, Fed.Rep.	1,691	87	1,176	1,299	3,794	3,642	5,356
Ireland	2,077	1	897	-	-	-	0
Lithuania	2,377	296	-	-	-	-	0
Netherlands	27,284	31,154	19,439	22,546	17,094	16,289	12,157
Norway	113	1,243	21	12,855	526	7,359	129
Sweden	491	53	35	402	-	-	0
UK (Engl. + Wales)	596	-	1,060	1,435	1,890	1,699	935
UK (Scotland)	300	625	6	4	111	93	240
Unallocated	-5,106	1,956	10,869	5,988	-116	0	0
Discard	78	139	-	1,036	2	0	0
Total	35,626	41,164	34,749	44,223	22,255	29523	21424

[1]Preliminary

Table 3.5.1. Catches (t) of *Trachurus mediterraneus* in Divisions VIIIab, VIIIc and Sub-Area VII

	VII	VIIIab	VIIIc East	VIIIc West	TOTAL
1989	0	23	3903		3926
1990	0	298	2943		3241
1991	0	2122	5020		7142
1992	0	1123	4804		5927
1993	0	649	5576		6225
1994	0	1573	3344		4917
1995	0	2271	4585		6856
1996	0	1175	3443		4618
1997	0	557	3264		3821
1998	0	740	3755		4495
1999	0	1100	1592		2692
2000	59	988	808		1854
2001	1	525	1293		1820
2002	1	525	1198		1724
2003	0	340	1699		2039
2004	0	53	841		894
2005	1	155	1005		1162
2006	1	168	794		963
2007	0	126	326		452
2008	0	82	405		487
2009	0	42	1082		1124
2010	0	97	370		467
2011	0	119	1096		1225
2012	0	186	667	116	865

Table 3.6.1 Horse mackerel general. Length distributions (%) Catches by fleet and country in 2012. (+ is <0.05%)

	Netherlands	Ireland	Norway	Germany	Spain		
	Pel. trawl	Pel. trawl	P.seine	Pel. trawl	P.seine	Trawl	Artisanal
cm	All	All	IVa	VIIb	VIIIbc	VIIIbc	VIIIbc
5							
6							
7							
8							
9							
10					+		
11					+	+	
12					0.09	+	
13					0.22	0.09	
14					0.45	1.16	
15					0.58	2.79	
16					1.21	8.47	
17	+				2.93	10.76	
18	0.50				2.65	7.91	
19	2.80				6.17	4.69	0.56
20	3.53				13.11	2.93	0.91
21	5.49				15.60	2.14	1.50
22	5.65	0.14			7.74	1.42	2.74
23	5.78	1.18			7.48	1.62	4.19
24	8.73	3.22			2.23	1.50	4.63
25	12.04	6.71		0.30	1.00	1.80	6.23
26	8.90	10.71		0.82	1.44	1.98	4.74
27	6.99	9.59	0.52	1.32	1.44	2.88	4.41
28	3.25	8.43	2.16	3.56	3.15	3.40	4.41
29	4.96	8.38	4.92	11.46	4.05	5.17	6.12
30	6.17	11.96	8.51	19.66	5.33	4.15	4.41
31	6.95	12.06	16.21	21.78	6.20	3.28	5.76
32	5.26	9.24	21.94	13.02	5.00	3.98	4.94
33	4.56	6.26	18.67	9.83	4.18	2.61	5.72
34	2.62	4.30	10.87	6.80	2.83	3.08	4.15
35	1.73	2.89	6.67	5.79	1.67	3.02	2.39
36	1.24	2.18	5.03	2.84	1.14	3.88	3.03
37	1.10	1.33	2.46	1.72	0.85	3.05	6.40
38	0.56	0.68	1.02	0.81	0.64	2.81	5.59
39	+	0.35	0.61	0.20	0.24	2.37	6.33
40	1.05	0.22	0.11		0.10	1.50	5.19
41		0.10	0.11		+	1.67	2.80
42+		0.08	0.20	0.10	0.20	3.87	2.83

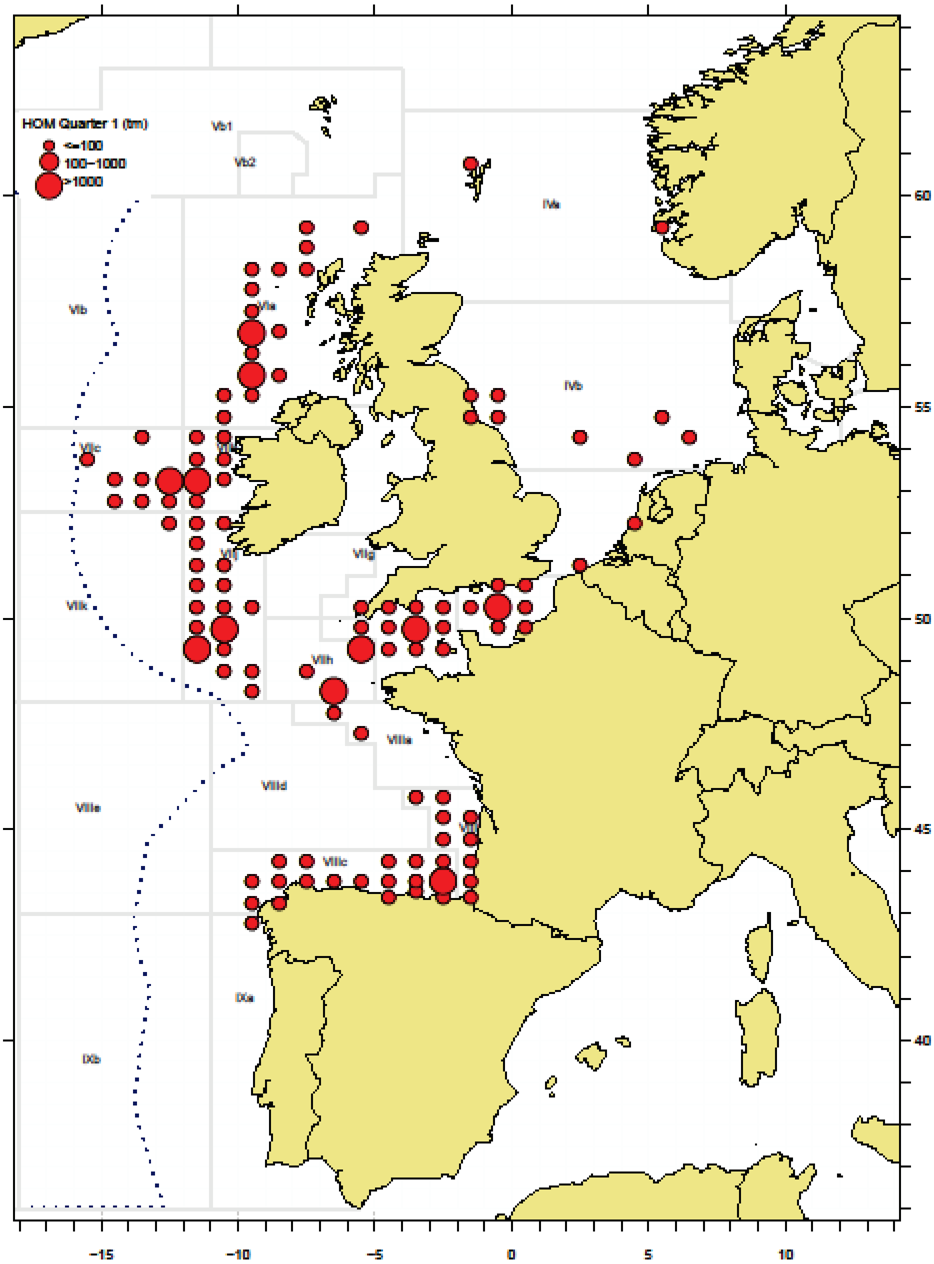

Figure 3.1.1a. Horse mackerel catches 1st quarter 2012

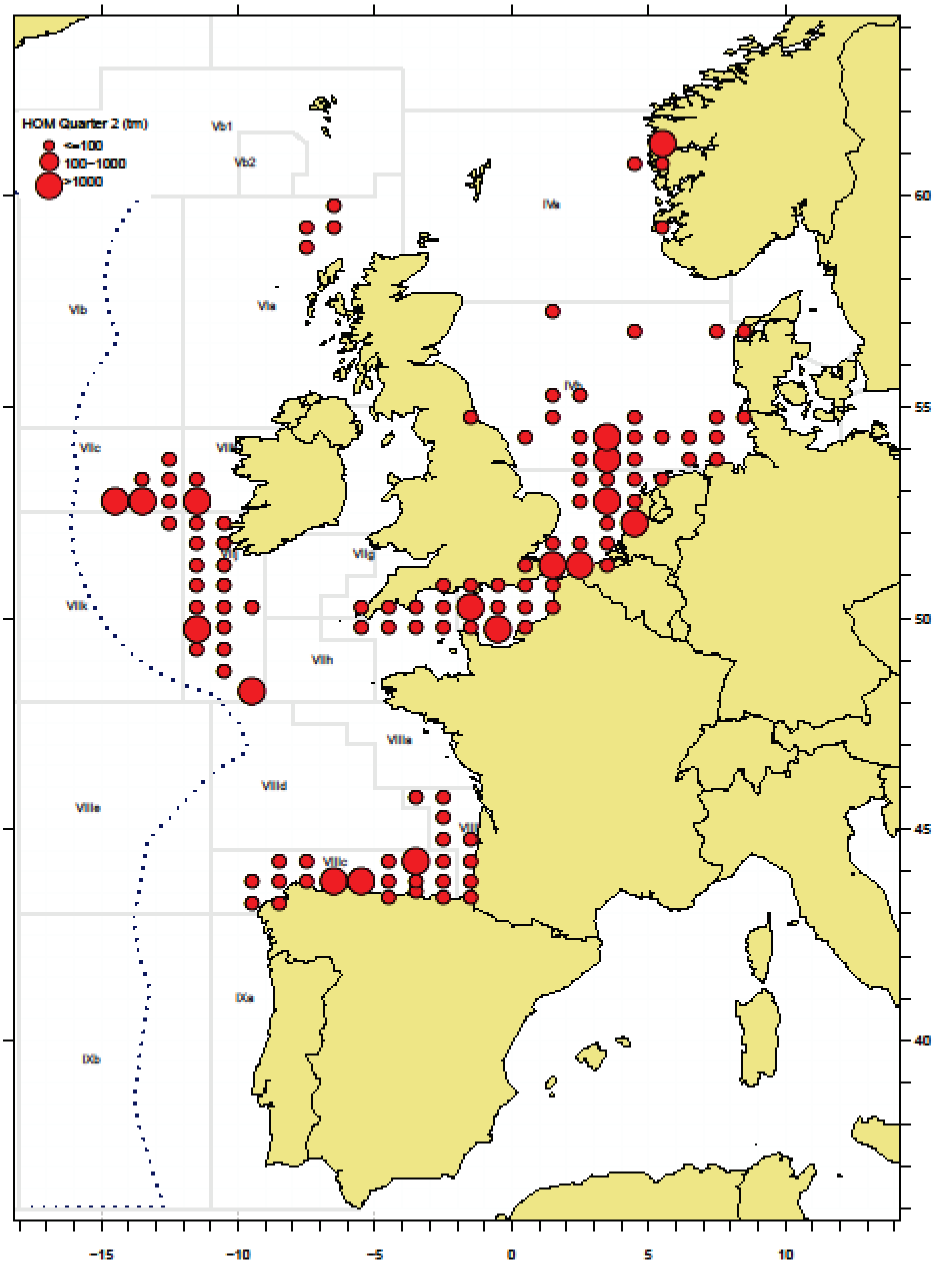

Figure 3.1.1b. Horse mackerel catches 2nd quarter 2012

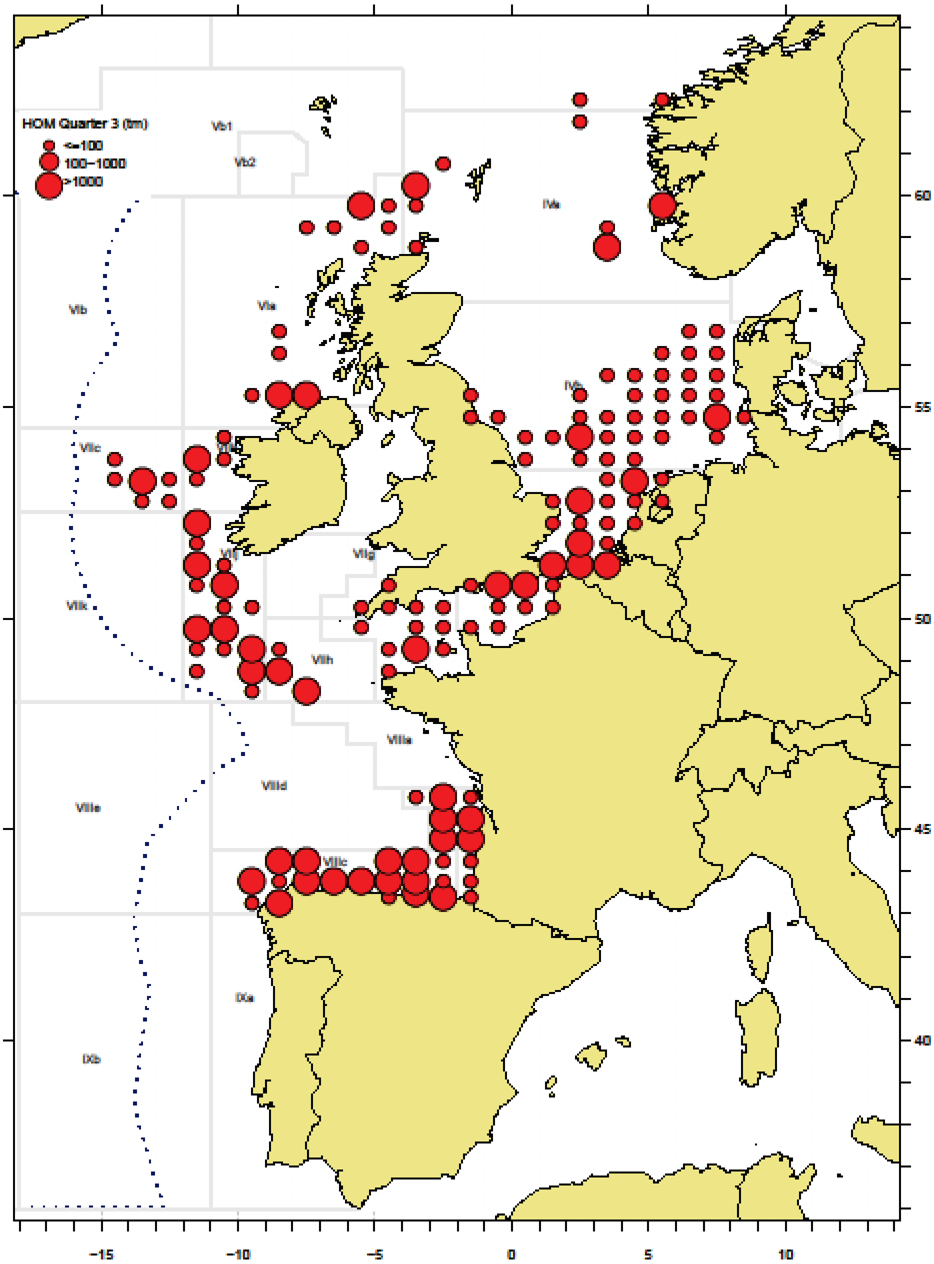

Figure 3.1.1c. Horse mackerel catches 3rd quarter 2012

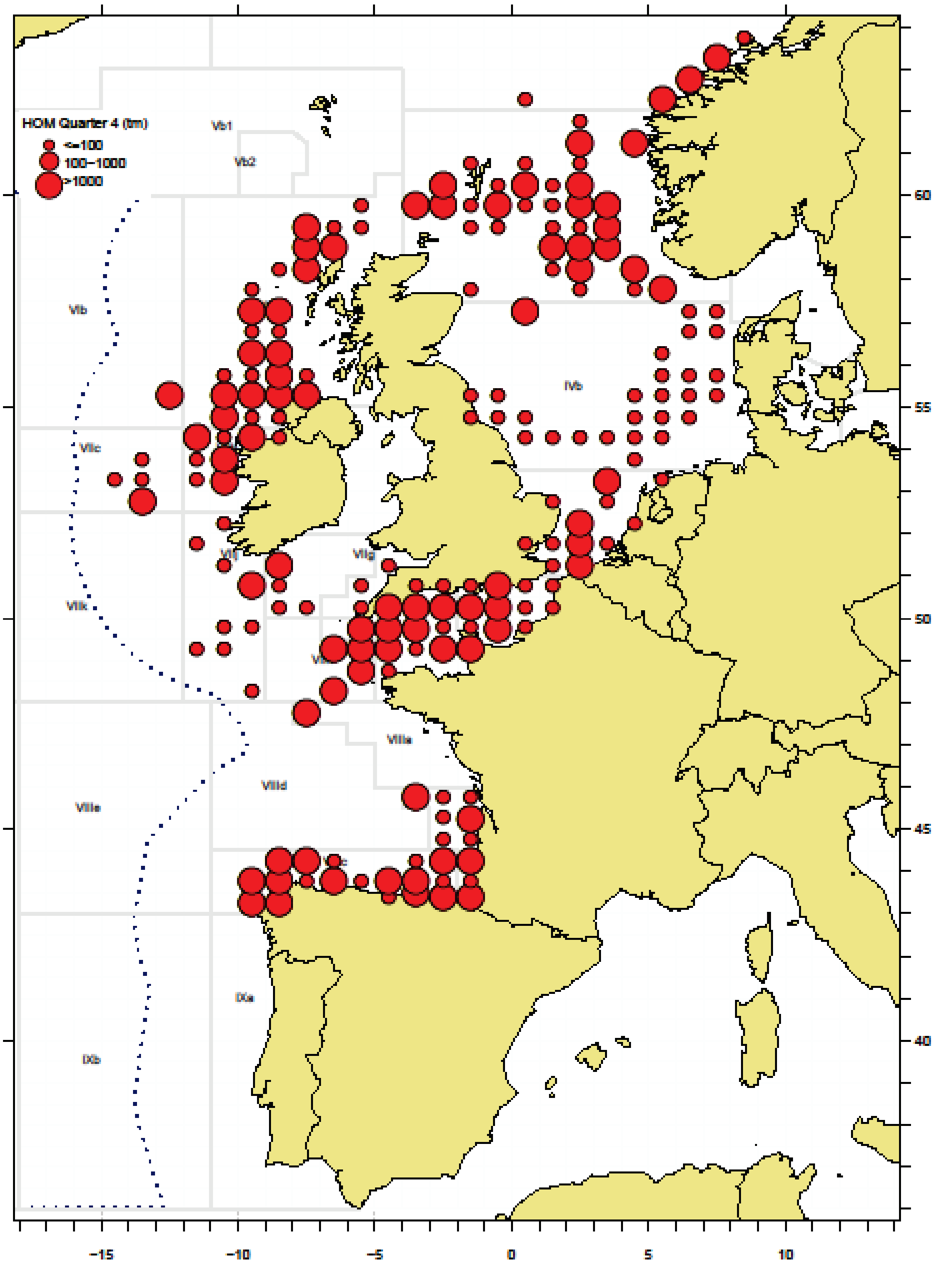

Figure 3.1.1d. Horse mackerel catches 4th quarter 2012

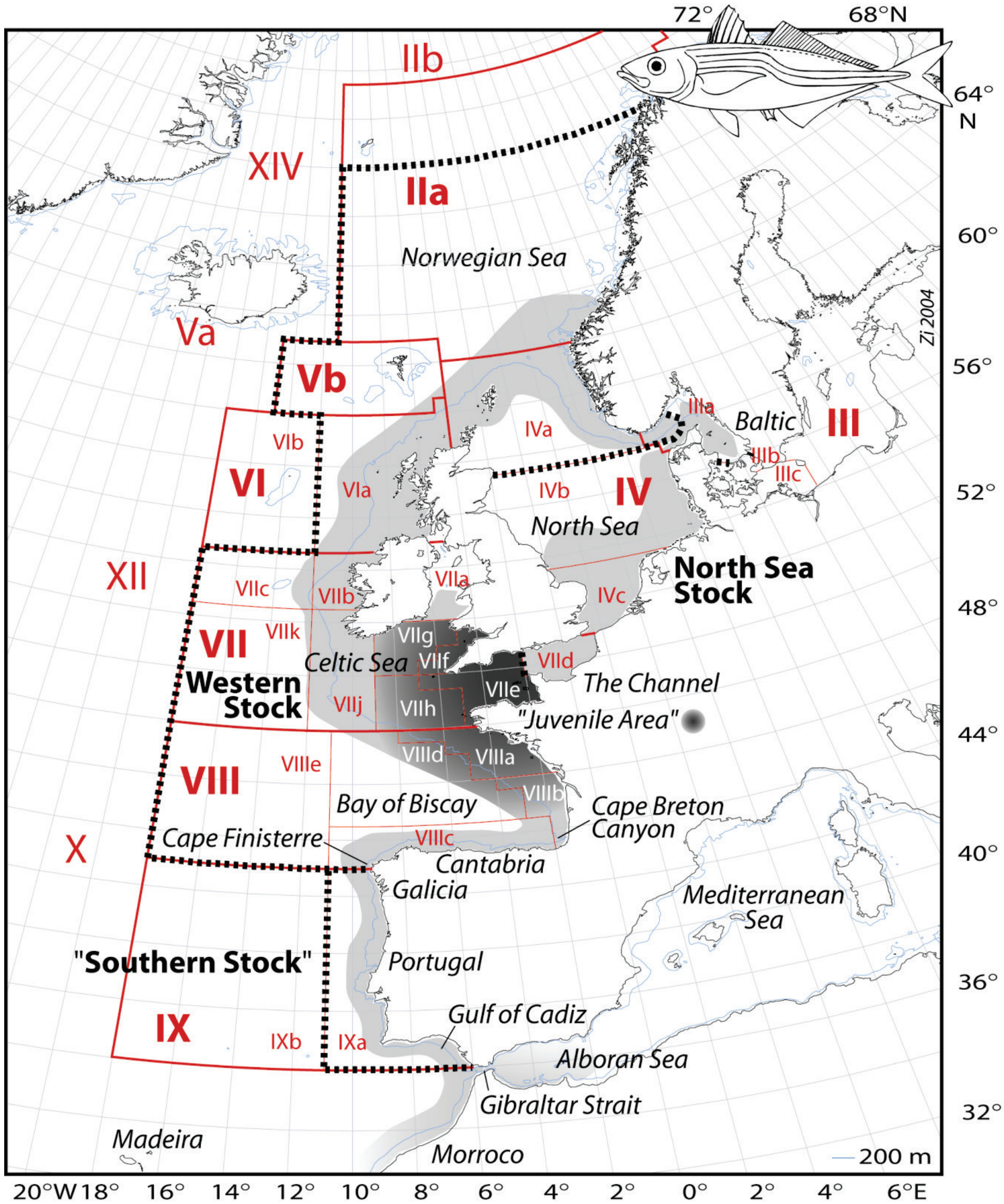

Figure 3.2.1: Distribution of Horse Mackerel in the Northeast-Atlantic: Stock definitions as used by the 2004 WG MHSA. Note that the "Juvenile Area" is currently only defined for the Western Stock distribution area – juveniles do also occur in other areas (like in Div. VIId). Map source: GEBCO, polar projection, 200 m depth contour drawn.

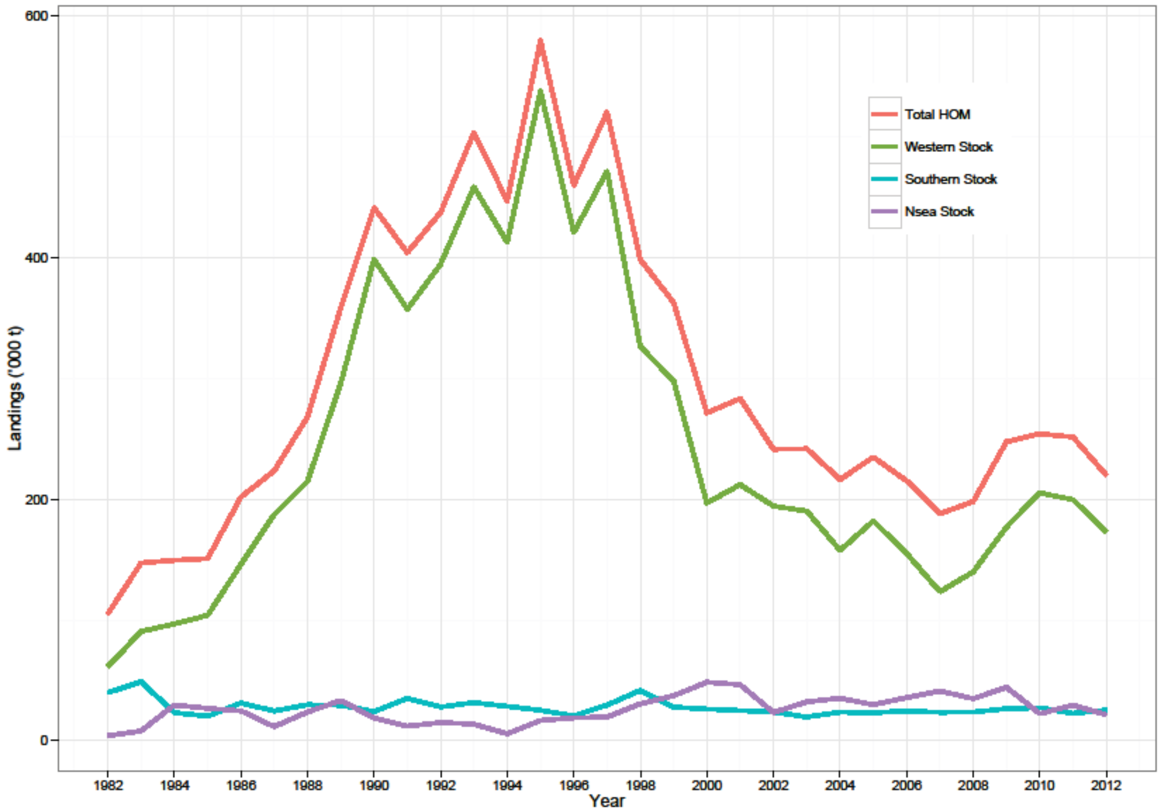

Figure 3.3.1 Horse mackerel general. Total catches in the northeast Atlantic during the period 1982 - 2012. The catches taken from the southern, western and North Sea horse mackerel stocks are shown in relation to the total catches in the northeast Atlantic. Caches from Div. VIIIc are transferred from southern stock to western stock from 1982 onwards. Southern horse mackerel is assessed by ICES WGHANSA since 2011.

4 North Sea Horse Mackerel: Divisions IVa (first and second quarters), IIIa (excluding Western Skagerrak in third and fourth quarter), IVb, IVc and VIId

4.1 ICES Advice Applicable to 2013

Based on ICES approach to data-limited stocks (category 5), ICES advised for 2013 that catches of horse mackerel in Divisions IIIa and VIa first and second quarter, IVb,c, and VIId (North Sea stock) should be no more than 25 500 tonnes, which represented a 20% precautionary reduction to recent catch levels. The TAC for IVbc and VIId in 2013 was 37,950 tonnes.

4.2 The Fishery in 2012 on the North Sea horse mackerel stock

Catches by the Danish industrial fleet for reduction into fishmeal and fish oil formed the majority of North Sea horse mackerel catches throughout the 1970s and 1980s. Catches were taken in the fourth quarter mainly in Divisions IVb and VIId. The 1990s saw a drop in the value of industrial resources, limited fishing opportunities and steep increases in fuel costs. In 2001, an individual quota scheme was introduced in Denmark, which resulted in a rapid restructuring of the fleet. Since then the fleet size has been radically reduced and now numbers less than 20% that in the 1980s and Danish North Sea horse mackerel catches have diminished. Since the 1990's, a larger portion of catches has been taken in a directed horse mackerel fishery for human consumption by the Dutch freezer-trawler fleet.

Catches taken in Divisions IVa and IIIa during the two first quarters and all year in divisions IVb, IVc and VIId are regarded North Sea horse mackerel (Table 3.3.1). Table 3.3.3 shows the reported national catches of this stock from 1997–2012. The catches were relatively low during the period 1982-1997 (not shown) with an average of 18,000 tons. The catches increased between 1998 (30,500 tons) and 2000 (48,400 tons). Between 2000 and 2010, the catches varied between 22,255 and 46,400 tons. In 2012 the catch was 21,424 tons, which is 27% less than in 2011. This difference is explained mostly by relatively high catches by Norway in 2011. Landings by ICES division are illustrated in Figure 4.2.1 for the period 1982 – 2012.

Denmark has traded parts of its quota with the Netherlands for fishing opportunities for other species, however due to the structure of the Danish quota management setup only a limited amount of quota can be made available for swaps with other countries. These practical implications of the management scheme largely explain the consistent underutilisation of the TAC (approximately 50% in 2010-2012) in recent years (see Figure 4.2.2).

4.2.1 Egg Surveys

No egg surveys for horse mackerel have been carried out in the North Sea since 1991. Such surveys were carried out during the period 1988-1991. SSB estimates are available historically. However, they were calculated assuming horse mackerel to be a determinate spawner. Horse mackerel is now considered an indeterminate spawner, Therefore egg abundance could only be considered a relative index of SSB. The mackerel egg surveys in the North Sea do not cover the spawning area of horse mackerel.

4.3 Biological Data

4.3.1 Catch in Numbers at Age

Table 4.3.1.1 shows catch numbers by quarter (and annual totals) by area in 2012. Annual catch numbers at age for 1995-2012 are given in Table 4.3.1.2. This year, English catches for the period 2008 – 2010 were included in the numbers at age by applying a raising factor. Age compositions for the period 1987–1995 are also available. However, these are based on samples taken from low numbers of Dutch commercial catches and catches from research vessels. These samples cover only a small proportion of the total catch and therefore only give a rough indication of the age composition of the stock (Figure 4.3.1).

In 2012, 49% of the landings were sampled but the samples are restricted to Dutch and UK (England) samples from division IVb and VIId in quarters 3 and 4. A total of 23 samples were collected (Section 1.3.1). Sampling coverage in 2012 has deteriorated compared to previous years. The catch at age data remains questionable and, .if an analytical assessment is to be carried out in the future, sampling coverage needs to be improved.

4.3.2 Mean weight at age and mean length at age

Tables 4.3.2.1 and 4.3.2.2 show mean weight and length at age by quarter and by area in 2012. The annual average values are also shown in those same Tables.

4.3.3 Maturity at age

There is no information available about the maturity at age of the North Sea Horse mackerel stock.

4.3.4 Natural mortality

There is no specific information available about natural mortality of this stock.

4.4 Data Exploration

4.4.1 Catch curves

The log-catch numbers were plotted by cohort to estimate the negative gradient of the slope and get an estimate of total mortality (Z). Fully selected ages 6 to 14 for the 1991 – 2012 period resulted in the 1989 to 1998 cohorts. Those were plotted in Figure 4.4.1.1. The estimated negative gradients by cohort are shown in Figure 4.4.1.2 where an increasing trend in total mortality for the period examined is suggested.

An analysis of the catch number at age data carried out in 2011 showed that only the 1 vs 2, 2 vs 3, 7vs 8 and 8 vs 9 age groups were positively and significantly correlated in the catch. This analysis was not updated this year but these results suggest limitations in the catch at age data.

4.4.2 Alternative methods to estimate the biomass

In 2002 Ruckert *et al.* estimated the north sea horse mackerel biomass based on a ratio estimate that related CPUE data from the IBTS to CPUE data of whiting (Merlangius merlangus). The applied method assumes that length specific catchability of whiting and horse mackerel are the same for the IBTS gear. Subsequently, they use the total biomass of whiting derived from an analytical stock assessment (MSVPA) to estimate the relationship between CPUE and biomass.

Other methods to use information from data-rich stocks to assess the biomass of data poor stocks have recently been suggested by Punt *et al*. (2011). WGWIDE suggests that these methods should be further investigated to enable stock estimates of the North Sea horse mackerel.

4.4.3 IBTS Survey Data

IBTS data from quarter 3 were obtained from DATRAS and analysed. Based on a comparison of IBTS data from 4 quarters in the period 1991-1996, Ruckert *et al* (2002) showed that horse mackerel catches in the IBTS were most abundant in the third quarter of the year. In contrast to previous years, when during WGWIDE meetings, three indices were derived: (a) for fish <14 cm, (b) for fish >= 14 cm and <23 cm and (c) for fish >=23 cm, the working group in 2013 considered that using an 'exploitable biomass index' is most appropriate for the purpose of interpreting trend in the stock. Many pelagic species are frequently found close to the bottom during daytime (which is when the IBTS survey operates) and migrate upwards predominantly during the night they are susceptible to semi-pelagic fishing gear and to bottom trawls (Barange *et al*. 1998). Eaton *et al* (1983) argued that horse mackerel of 2 years and older are predominantly demersal in habit. Commercial catch data show that 2-year old fish and older make up 96% of the landings, which roughly coincides with fish of >= 20 cm (see Figure 4.4.3.1). A biomass index including fish of 20 cm and larger was therefore derived for the interpretation of stock trend.

To create a cpue index, a subset of ICES rectangles was selected. Rectangles that were not covered by the survey more than once during the period 1991-2012 were excluded from the index area. In 2012, WGWIDE expressed concern that the previously selected index area did not sufficiently cover the distribution area of the stock, especially in years that the stock would be relatively more abundant and spread out more. Ruckert *et al* (2002) also identified a larger distribution area of the North Sea stock. Based on the above, 61 rectangles were identified to be included in the index area as shown in Figure 4.4.3.2. To calculate the biomass index for the 20+ cm class, weight per cm length class was calculated using length-weight information from a fitted function to IBTS 2003-2009 weight data:

$$W = 0.0161 * L^{2.86}$$

where W=weight in grams and L= length in cm. Sums were then calculated per rectangle and the mean was subsequently taken over all rectangles. The working group noted in previous years that the smaller individuals (<14 cm) showed highly variable cpue trends, while at larger age groups the variability decreased. Considering that only 20+ cm fish are selected it is considered by the working group that it is acceptable to use the cpue data in its current form, but it is recommended to explore transformations of the data to take better account of zeros and extraordinarily large data points in the data set, especially when the use of the IBTS data in developing an assessment model for this stock is further pursued. The index is shown in Figure 4.4.3.3.

4.5 Basis for 2013 Advice

Based on the guidelines for data-limited stocks (DLS) for which a biomass index is available. In the case of North Sea horse mackerel a relative index of biomass of fish >20 cm length derived from 3rd quarter IBTS was used (Table 4.5.1). The harvest control rule is an index-adjusted status-quo catch. The advice is based on a comparison of the two most recent index values with the three preceding values, combined with recent catch or landings data. Knowledge about the exploitation status also influences the advised catch.

For this stock the biomass is estimated to have increased by 54%. This increase is more than 20 % between 2008- 2010 (average of the three years = 0.0191) and 2011-2012 (average of the two years = 0.0295). According to the guidelines for DLS this implies an increase of landings of at most 20% in relation to the last three years average landings (L3YRS AV L = 24,341 tonnes), corresponding to landings of no more than 29,210 t

Additionally, considering that exploitation is unknown, ICES advises that landings should decrease by a further 20% as a precautionary buffer. This results in landings of no more than 23,368 t in 2014.

Although the harvest control rule indicates an increase in biomass >50% the index requires further exploration to be used reliably for assessment purposes (see Section 4.4.2 above). Advice relates to landings. Discards are known to take place but cannot be quantified, therefore total catches cannot be calculated.

4.6 Management considerations

In the past, Division VIId was included in the management area for Western horse mackerel together with Divisions IIa, VIIa–c, VIIe–k, VIIIa, VIIIb, VIIId, VIIIe, Subarea VI, EU and international waters of Division Vb, and international waters of Subareas XII and XIV. ICES considers Division VIId to be part of the North Sea horse mackerel distribution area. Since 2010, the EU TAC for the North Sea area has included Divisions IVb,c and VIId. Considering that a majority of the catches are taken in Division VIId, the total of North Sea horse mackerel catches are effectively constrained by the TAC since the realignment of the management areas in 2010.

Division IVa has since 2010 been included in the Western horse mackerel management area. There is no TAC for Division IIIa. Catches in area IVa and IIIa are considered negligible and, at present, are not thought to be detrimental to the stock (see Figure 4.2.1).

4.7 The assessment area of North Sea horse mackerel also includes catches from Divisions IIIa and IVa in quarters 1 and 2.

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Table 4.3.1.1 North Sea Horse Mackerel stock. Catch in numbers (1000) by quarter and area in 2012.

1Q						
Ages	IIIa	IVa	IVb	IVc	VIId	Total
0						
1						
2	0.02	124.00	0.08	1.11	485.79	611.00
3	0.04	259.36	0.17	2.33	1155.15	1417.04
4	0.07	497.57	0.32	3.35	1566.46	2067.78
5	0.05	350.21	0.23	1.28	647.04	998.81
6	0.05	338.21	0.22	0.42	372.98	711.88
7	0.02	124.74	0.08		181.44	306.28
8	0.01	83.16	0.05		159.82	243.04
9	0.01	83.16	0.05		73.09	156.32
10	0.02	124.74	0.08		32.90	157.74
11	0.00	14.84	0.01	0.13	31.73	46.72
12						
13						
14						
15+						
Sum	0.29	1999.97	1.30	8.63	4706.40	6716.59
2Q						
Ages	IIIa	IVa	IVb	IVc	VIId	Total
0						
1						
2	0.06	45.33	23.15	110.44	1943.12	2122.10
3	0.12	94.81	48.43	231.01	4620.49	4994.85
4	0.23	181.89	92.91	633.77	6265.71	7174.50
5	0.16	128.02	65.39	629.56	2588.11	3411.25
6	0.15	123.63	63.15	745.93	1491.89	2424.76
7	0.06	45.60	23.29	301.68	725.75	1096.38
8	0.04	30.40	15.53	201.12	639.25	886.33
9	0.04	30.40	15.53	201.12	292.36	539.45
10	0.06	45.60	23.29	301.68	131.61	502.24
11	0.01	5.43	2.77	13.22	126.91	148.33
12						
13						
14						
15+						
Sum	0.92	731.09	373.45	3369.54	18825.19	23300.19

Table 4.3.1.1 North Sea Horse Mackerel stock. Catch in numbers (1000) by quarter and area in 2012. Cont.

3Q Ages	IIIa	IVa	IVb	IVc	VIId	Total
0						
1						
2			35.67	179.34	695.60	910.60
3			74.61	375.11	1654.04	2103.76
4			108.36	539.24	2242.99	2890.59
5			42.79	205.83	926.49	1175.11
6			16.16	68.20	534.06	618.42
7			1.11		259.80	260.91
8			0.74		228.84	229.58
9			0.74		104.66	105.40
10			1.11		47.11	48.22
11			4.27	21.47	45.43	71.17
12						
13						
14						
15+						
Sum			285.56	1389.19	6739.02	8413.76

4Q Ages	IIIa	IVa	IVb	IVc	VIId	Total
0						
1					9491.30	9491.30
2			0.06		20662.93	20662.99
3			0.13		11900.31	11900.44
4			61.57	616.72	27432.73	28111.03
5			102.39	1027.87	19048.61	20178.87
6			143.27	1439.02	15482.33	17064.62
7			61.39	616.72	790.20	1468.32
8			40.93	411.15	3179.69	3631.77
9			40.93	411.15	3382.66	3834.74
10			61.39	616.72	143.85	821.97
11			0.01		220.71	220.71
12					110.35	110.35
13						
14					167.50	167.50
15+						
Sum			512.06	5139.37	112013.17	117664.60

Table 4.3.1.1 North Sea Horse Mackerel stock. Catch in numbers (1000) by quarter and area in 2012. Cont.

1-4Q Ages	IIIa	IVa	IVb	IVc	VIId	Total
0						
1					9491.30	9491.30
2	0.07	169.32	58.96	290.90	23787.44	24306.69
3	0.16	354.16	123.33	608.46	19329.98	20416.09
4	0.30	679.46	263.17	1793.08	37507.89	40243.89
5	0.21	478.23	210.80	1864.55	23210.25	25764.04
6	0.20	461.84	222.80	2253.58	17881.26	20819.69
7	0.08	170.34	85.88	918.41	1957.19	3131.88
8	0.05	113.56	57.25	612.27	4207.59	4990.72
9	0.05	113.56	57.25	612.27	3852.77	4635.90
10	0.08	170.34	85.88	918.41	355.48	1530.17
11	0.01	20.27	7.06	34.82	424.77	486.93
12					110.35	110.35
13						
14					167.50	167.50
15+						
Sum	1.21	2731.06	1172.37	9906.73	142283.77	156095.15

Table 4.3.1.2. Catch in numbers at age (millions), weight at age (kg) and length at age (cm) for the North Sea horse mackerel 1995-2012.

millions	Catch number																	
Age	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
1	1.76	4.58	12.56	2.30	12.42	70.23	12.81	60.42	13.81	15.65	52.39	5.01	3.40	1.73	34.10	3.31	8.14	9.49
2	3.12	13.78	27.24	22.13	31.45	77.98	36.36	16.82	56.15	17.54	29.82	23.72	15.46	8.84	13.91	22.52	23.30	24.31
3	7.19	11.04	14.07	36.69	23.13	28.41	174.34	19.27	23.44	34.38	27.80	61.47	22.83	36.13	28.43	10.67	76.51	20.42
4	10.32	11.87	14.93	38.82	17.59	21.42	87.81	11.90	33.21	14.51	12.58	40.86	82.64	16.72	22.06	15.70	37.27	40.24
5	12.08	9.64	14.58	20.79	23.12	31.27	18.51	5.61	26.93	27.77	16.66	72.95	71.23	36.35	17.25	23.68	14.58	25.76
6	13.16	12.49	12.38	12.10	26.19	19.64	11.49	5.83	10.59	20.17	5.19	23.38	30.52	36.10	16.28	15.93	9.93	20.82
7	11.43	7.96	10.12	13.99	20.64	19.47	18.25	5.54	6.33	10.58	2.86	13.73	23.93	27.33	21.52	27.63	5.75	3.13
8	12.64	6.60	8.64	10.79	21.75	9.00	14.70	10.48	9.56	3.82	2.43	5.86	17.27	21.90	47.13	5.62	6.03	4.99
9	7.25	1.48	2.45	8.26	12.91	11.50	10.22	6.33	10.90	5.37	3.80	1.58	7.89	10.16	11.24	6.34	3.36	4.64
10	5.87	5.31	0.75	4.01	8.21	8.96	9.98	6.75	1.51	10.95	5.76	1.36	1.66	7.52	9.28	8.30	10.13	1.53
11	0.01	0.29	0.34	2.72	2.14	6.98	9.58	5.12	3.43	6.22	2.31	0.19	0.59	1.92	7.24	2.88	6.90	0.49
12	8.84	1.28	0.25	0.71	0.43	3.07	5.35	3.02	3.29	4.47	4.13	1.69	0.21	2.10	3.65	0.30	3.61	0.11
13	0.20	8.92		1.81	1.40	1.61	3.73	2.17	2.25	6.16	2.50	0.62	0.72	0.36	0.30	0.34	0.77	
14	4.37	8.01	1.38	0.31	3.78		1.95	1.29	3.40	2.25	9.86	0.96	0.65	2.42	0.90	0.23	0.33	0.17
15+				5.11	4.03	12.22	5.81	2.71	4.70	8.52	9.55	0.82		1.03	6.14	1.13	0.53	

kg	weight																	
Age	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
1	0.076	0.107	0.063	0.063	0.063	0.075	0.055	0.066	0.073	0.076	0.079	0.069	0.073	0.063	0.063	0.077	0.060	0.069
2	0.126	0.123	0.102	0.102	0.102	0.101	0.072	0.095	0.105	0.104	0.077	0.095	0.082	0.096	0.096	0.101	0.092	0.090
3	0.125	0.143	0.126	0.126	0.126	0.136	0.071	0.129	0.123	0.120	0.103	0.116	0.105	0.109	0.109	0.115	0.098	0.118
4	0.133	0.156	0.142	0.142	0.142	0.152	0.082	0.154	0.137	0.147	0.132	0.124	0.115	0.125	0.125	0.138	0.116	0.142
5	0.146	0.177	0.160	0.160	0.160	0.166	0.120	0.172	0.166	0.174	0.158	0.141	0.130	0.145	0.145	0.154	0.146	0.152
6	0.164	0.187	0.175	0.175	0.175	0.194	0.183	0.195	0.181	0.198	0.196	0.177	0.164	0.161	0.161	0.180	0.167	0.172
7	0.161	0.203	0.199	0.199	0.199	0.198	0.197	0.216	0.195	0.225	0.251	0.210	0.191	0.194	0.194	0.207	0.188	0.183
8	0.178	0.195	0.231	0.231	0.231	0.213	0.201	0.227	0.212	0.229	0.270	0.244	0.197	0.221	0.221	0.195	0.206	0.188
9	0.165	0.218	0.250	0.250	0.250	0.247	0.235	0.228	0.238	0.256	0.280	0.231	0.256	0.286	0.286	0.241	0.300	0.212
10	0.173	0.241	0.259	0.259	0.259	0.280	0.246	0.251	0.259	0.291	0.291	0.284	0.258	0.296	0.296	0.225	0.324	0.204
11	0.317	0.307	0.300	0.300	0.300	0.279	0.260	0.302	0.245	0.301	0.344	0.237	0.517	0.273	0.273	0.286	0.341	0.274
12	0.233	0.211	0.329	0.329	0.329	0.342	0.286	0.292	0.295	0.300	0.361	0.257	0.279	0.309	0.309	0.227	0.402	0.195
13	0.241	0.258	0.367	0.367	0.367	0.318	0.287	0.318	0.356	0.302	0.332	0.268	0.338	0.375	0.375	0.288	0.405	
14	0.348	0.277	0.299	0.299	0.299	0.325	0.295	0.319	0.319	0.338	0.376	0.291	0.414	0.277	0.277	0.315	0.415	0.187
15+	0.348	0.277	0.360	0.360	0.360	0.332	0.336	0.390	0.380	0.401	0.367	0.402		0.389	0.389	0.358	0.473	

cm	length

Age	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
1	19.2	19.2	19.2	19.2	19.2	19.0	18.7	17.1	20.2	19.8	20.54	19.89	20.05	20.00	20.00	20.77	19.17	19.90
2	22.0	22.0	22.0	22.0	22.0	21.5	20.4	21.4	22.4	22.2	21.49	21.94	20.83	21.62	21.62	22.60	21.70	21.67
3	23.5	23.5	23.5	23.5	23.5	23.9	20.6	22.9	23.8	23.6	23.00	23.38	22.59	23.20	23.20	23.75	23.06	23.53
4	24.8	24.8	24.8	24.8	24.8	24.9	21.3	24.9	24.6	25.2	24.69	24.13	23.64	24.11	24.11	24.98	24.48	25.02
5	25.5	25.5	25.5	25.5	25.5	26.0	25.0	26.2	26.2	26.6	25.53	25.42	24.37	25.61	25.61	25.69	25.87	25.70
6	26.4	26.4	26.4	26.4	26.4	27.8	27.4	26.6	27.3	27.5	27.77	27.01	26.58	26.33	26.33	27.02	27.54	26.96
7	27.2	27.2	27.2	27.2	27.2	28.3	28.0	27.4	28.2	28.9	30.42	28.53	27.80	28.07	28.07	28.23	28.02	27.09
8	29.2	29.2	29.2	29.2	29.2	28.6	28.4	28.2	29.0	29.2	31.19	29.84	28.12	28.77	28.77	28.17	27.71	27.05
9	29.5	29.5	29.5	29.5	29.5	30.0	29.7	29.2	29.9	30.5	31.82	30.63	30.05	31.16	31.16	30.19	31.88	28.56
10	29.5	29.5	29.5	29.5	29.5	31.3	30.2	30.8	30.8	31.5	32.32	31.55	31.15	31.79	31.79	29.91	32.45	28.04
11	30.6	30.6	30.6	30.6	30.6	31.4	30.7	32.5	30.8	32.0	34.41	31.18	39.50	31.60	31.60	32.09	33.30	30.06
12	32.1	32.1	32.1	32.1	32.1	33.7	32.0	33.8	31.9	31.8	36.16	30.75	31.50	32.24	32.24	29.57	34.49	27.50
13	33.3	33.3	33.3	33.3	33.3	33.5	31.7	33.8	32.9	32.0	34.20	32.13	33.40	33.90	33.90	31.83	35.21	
14	31.1	31.1	31.1	31.1	31.1	33.4	32.1	32.4	32.7	33.0	34.90	32.15	34.50	32.33	32.33	33.00	36.00	27.50
15+	32.5	32.5	32.5	32.5	32.5	33.4	33.4	34.4	34.6	34.8	35.39	35.42		35.12	35.12	34.69	36.95	

Table 4.3.2.1 North Sea Horse Mackerel stock. Mean weight at age (kg) in the catch by quarter and area in 2012.

1Q						
Ages	IIIa	IVa	IVb	IVc	VIId	Total
0						
1						
2	0.072	0.072	0.072	0.072	0.099	0.094
3	0.091	0.091	0.091	0.091	0.117	0.112
4	0.105	0.105	0.105	0.104	0.136	0.128
5	0.132	0.132	0.132	0.120	0.146	0.141
6	0.151	0.151	0.151	0.139	0.167	0.159
7	0.172	0.172	0.172		0.187	0.181
8	0.193	0.193	0.193		0.191	0.192
9	0.199	0.199	0.199		0.212	0.205
10	0.179	0.179	0.179		0.217	0.187
11	0.103	0.103	0.103	0.103	0.279	0.223
12						
13						
14						
15+						
Mean	0.140	0.140	0.140	0.063	0.175	0.162
2Q						
Ages	IIIa	IVa	IVb	IVc	VIId	Total
0						
1						
2	0.072	0.072	0.072	0.072	0.099	0.097
3	0.091	0.091	0.091	0.091	0.117	0.115
4	0.105	0.105	0.105	0.106	0.136	0.132
5	0.132	0.132	0.132	0.137	0.146	0.144
6	0.151	0.151	0.151	0.152	0.167	0.161
7	0.172	0.172	0.172	0.172	0.187	0.182
8	0.193	0.193	0.193	0.193	0.191	0.191
9	0.199	0.199	0.199	0.199	0.212	0.206
10	0.179	0.179	0.179	0.179	0.217	0.189
11	0.103	0.103	0.103	0.103	0.279	0.254
12						
13						
14						
15+						
Mean	0.140	0.140	0.140	0.140	0.175	0.167

Table 4.3.2.1 North Sea Horse Mackerel stock. Mean weight at age (kg) in the catch by quarter and area in 2012. Cont.

3Q Ages	IIIa	IVa	IVb	IVc	VIId	Total
0						
1						
2			0.072	0.072	0.099	0.093
3			0.091	0.091	0.117	0.111
4			0.104	0.104	0.136	0.129
5			0.121	0.120	0.146	0.141
6			0.141	0.139	0.167	0.163
7			0.172		0.187	0.186
8			0.193		0.191	0.191
9			0.199		0.212	0.212
10			0.179		0.217	0.216
11			0.103	0.103	0.279	0.215
12						
13						
14						
15+						
Mean			0.137	0.063	0.175	0.166
4Q Ages	**IIIa**	**IVa**	**IVb**	**IVc**	**VIId**	**Total**
0						
1					0.069	0.069
2			0.072		0.090	0.089
3			0.091		0.122	0.122
4			0.108	0.108	0.147	0.146
5			0.141	0.141	0.155	0.154
6			0.153	0.153	0.177	0.175
7			0.172	0.172	0.196	0.185
8			0.193	0.193	0.186	0.186
9			0.199	0.199	0.216	0.214
10			0.179	0.179	0.390	0.216
11			0.103		0.318	0.318
12					0.195	0.195
13						
14					0.187	0.187
15+						
Mean			0.101	0.082	0.175	0.174

Table 4.3.2.1 North Sea Horse Mackerel stock. Mean weight at age (kg) in the catch by quarter and area in 2012. Cont.

1-4Q Ages	IIIa	IVa	IVb	IVc	VIId	Total
0						
1					0.069	0.069
2	0.072	0.072	0.072	0.072	0.091	0.090
3	0.091	0.091	0.091	0.091	0.120	0.118
4	0.105	0.105	0.105	0.106	0.144	0.142
5	0.132	0.132	0.134	0.137	0.153	0.152
6	0.151	0.151	0.152	0.152	0.176	0.172
7	0.172	0.172	0.172	0.172	0.190	0.183
8	0.193	0.193	0.193	0.193	0.187	0.188
9	0.199	0.199	0.199	0.199	0.215	0.212
10	0.179	0.179	0.179	0.179	0.287	0.204
11	0.103	0.103	0.103	0.103	0.299	0.274
12					0.195	0.195
13						
14					0.187	0.187
15+						
Mean	0.100	0.100	0.100	0.100	0.165	0.168

Table 4.3.2.2. North Sea Horse Mackerel stock. Mean length (cm) at age in the catch by quarter and area in 2012.

1Q						
Ages	IIIa	IVa	IVb	IVc	VIId	Total
0						
1						
2	19.69	19.69	19.69	19.69	21.92	21.46
3	21.28	21.28	21.28	21.28	23.31	22.93
4	22.75	22.75	22.75	22.61	24.67	24.20
5	24.41	24.41	24.41	23.98	25.34	25.01
6	25.97	25.97	25.97	25.37	26.14	26.06
7	26.83	26.83	26.83		27.27	27.09
8	27.50	27.50	27.50		27.51	27.51
9	27.50	27.50	27.50		28.37	27.91
10	27.17	27.17	27.17		28.50	27.45
11	23.50	23.50	23.50	23.50	30.50	28.25
12						
13						
14						
15+						
Mean	24.66	24.66	24.66	13.64	26.35	25.79
2Q						
Ages	IIIa	IVa	IVb	IVc	VIId	Total
0						
1						
2	19.69	19.69	19.69	19.69	21.92	21.73
3	21.28	21.28	21.28	21.28	23.31	23.16
4	22.75	22.75	22.75	22.87	24.67	24.44
5	24.41	24.41	24.41	24.55	25.34	25.14
6	25.97	25.97	25.97	26.03	26.14	26.09
7	26.83	26.83	26.83	26.83	27.27	27.12
8	27.50	27.50	27.50	27.50	27.51	27.51
9	27.50	27.50	27.50	27.50	28.37	27.97
10	27.17	27.17	27.17	27.17	28.50	27.52
11	23.50	23.50	23.50	23.50	30.50	29.49
12						
13						
14						
15+						
Mean	24.66	24.66	24.66	24.69	26.35	26.02

Table 4.3.2.2. North Sea Horse Mackerel stock. Mean length (cm) at age in the catch by quarter and area in 2012. Cont.

3Q						
Ages	IIIa	IVa	IVb	IVc	VIId	Total
0						
1						
2			19.69	19.69	21.92	21.39
3			21.28	21.28	23.31	22.88
4			22.61	22.61	24.67	24.21
5			24.01	23.98	25.34	25.05
6			25.48	25.37	26.14	26.04
7			26.83		27.27	27.27
8			27.50		27.51	27.51
9			27.50		28.37	28.36
10			27.17		28.50	28.47
11			23.50	23.50	30.50	27.97
12						
13						
14						
15+						
Mean			24.56	13.64	26.35	25.91
4Q						
Ages	IIIa	IVa	IVb	IVc	VIId	Total
0						
1					19.90	19.90
2			19.69		21.68	21.68
3			21.28		23.88	23.88
4			23.17	23.17	25.37	25.32
5			24.70	24.70	25.94	25.87
6			26.07	26.07	27.26	27.15
7			26.83	26.83	27.22	27.04
8			27.50	27.50	26.79	26.88
9			27.50	27.50	28.82	28.66
10			27.17	27.17	34.50	28.45
11			23.50		31.50	31.50
12					27.50	27.50
13						
14					27.50	27.50
15+						
Mean			17.67	13.07	24.85	26.26

Table 4.3.2.2. North Sea Horse Mackerel stock. Mean length (cm) at age in the catch by quarter and area in 2012. Cont.

1-4Q Ages	IIIa	IVa	IVb	IVc	VIId	Total
0						
1					19.90	19.90
2	19.69	19.69	19.69	19.69	21.71	21.67
3	21.28	21.28	21.28	21.28	23.66	23.53
4	22.75	22.75	22.79	22.89	25.18	25.02
5	24.41	24.41	24.47	24.57	25.83	25.70
6	25.97	25.97	26.00	26.04	27.11	26.96
7	26.83	26.83	26.83	26.83	27.25	27.09
8	27.50	27.50	27.50	27.50	26.97	27.05
9	27.50	27.50	27.50	27.50	28.77	28.56
10	27.17	27.17	27.17	27.17	30.93	28.04
11	23.50	23.50	23.50	23.50	31.02	30.06
12					27.50	27.50
13						
14					27.50	27.50
15+						
Mean	17.61	17.61	17.62	17.64	24.52	26.04

Table 4.5.1. North Sea horse mackerel. IBTS index of fishable Biomass fish >=20 cm length.

	Fishable Biomass 20 cm+	Relative Index
1995	12016183.87	0.154327817
1996	11587486.14	0.148821911
1997	4050763.77	0.052025297
1998	3071869.49	0.039453034
1999	3020550.37	0.038793926
2000	8858869.43	0.113777385
2001	6029482.32	0.077438632
2002	6833491.88	0.087764793
2003	3264509.43	0.041927172
2004	2631894.20	0.033802286
2005	3860080.12	0.049576284
2006	3007696.15	0.038628835
2007	564070.50	0.007244544
2008	2155096.97	0.027678622
2009	755114.01	0.009698179
2010	1559471.94	0.020028813
2011	1273166.02	0.016351692
2012	3321629.15	0.04266078
SUM	77861425.74	1

Figure 4.2.1 North Sea horse mackerel. Catch by ICES Division for 1982-2012

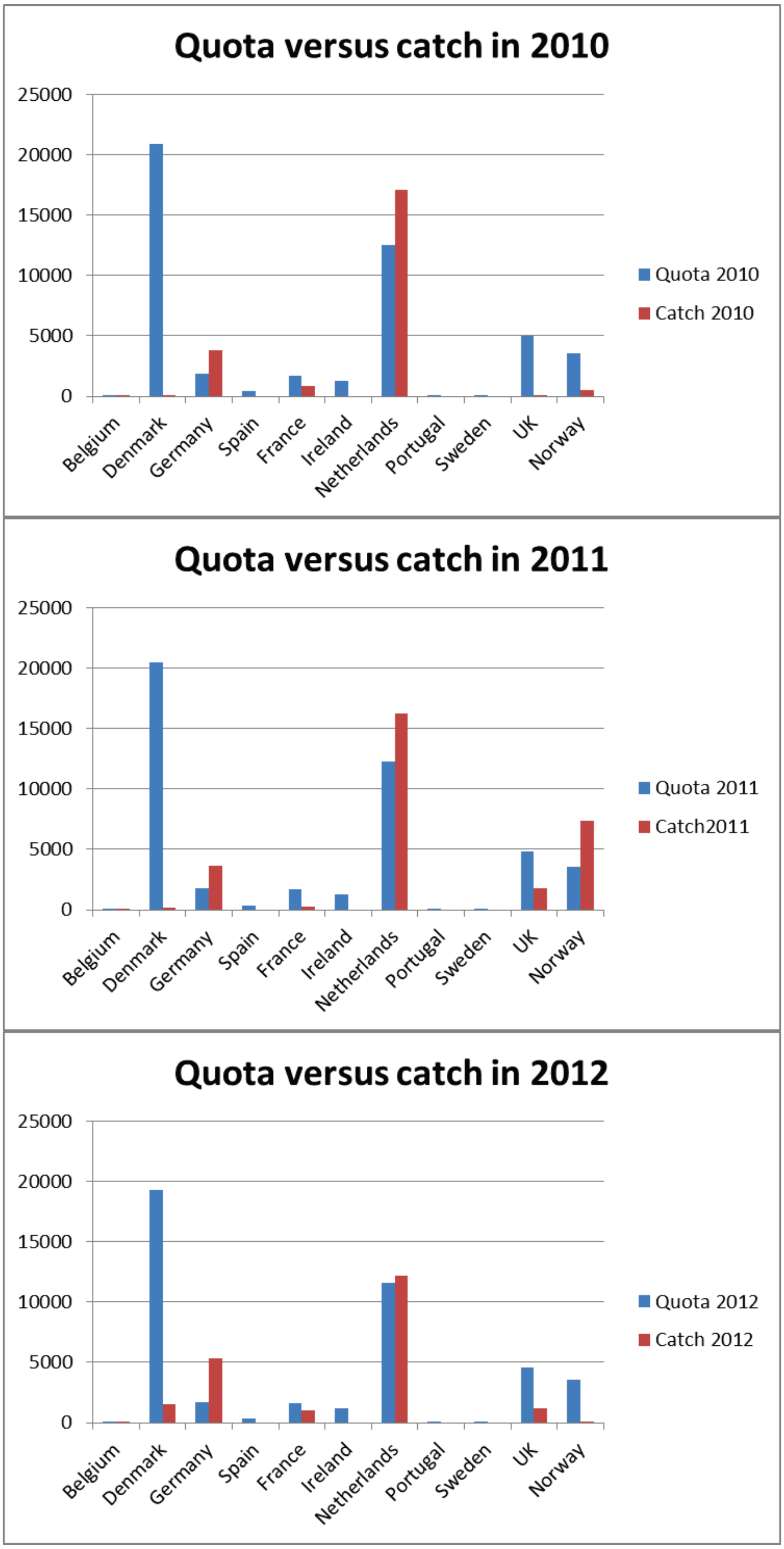

Figure 4.2.2. Utilisation of quota by country. Total under-utilisation of EU quota equals 49.8%, 51.7% and 52.4 % in 2010, 2011 and 2012 respectively.

Figure 4.3.1 North Sea horse mackerel. Age distribution in the catch for 1987-2012

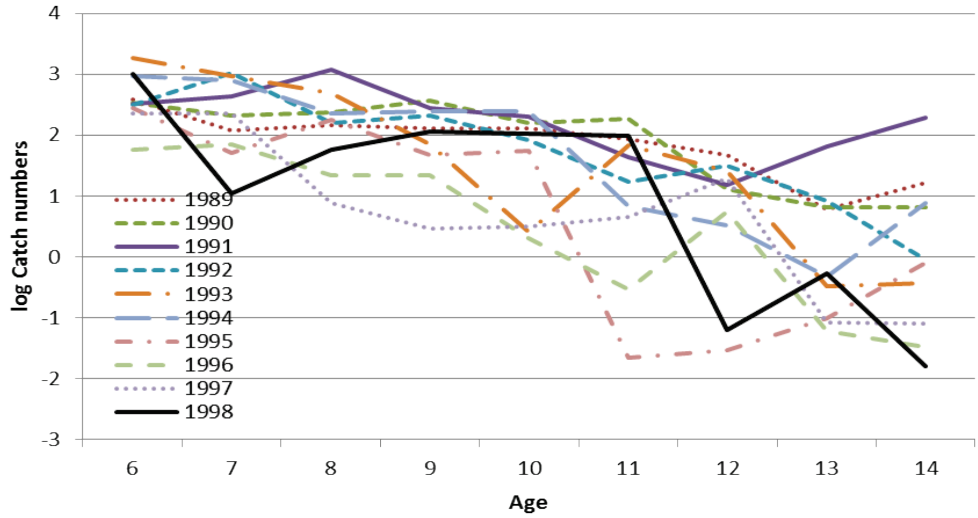

Figure 4.4.1.1. North Sea Horse Mackerel. Catch curves for the 1989 to 1998 cohorts, ages from 6 to 14.

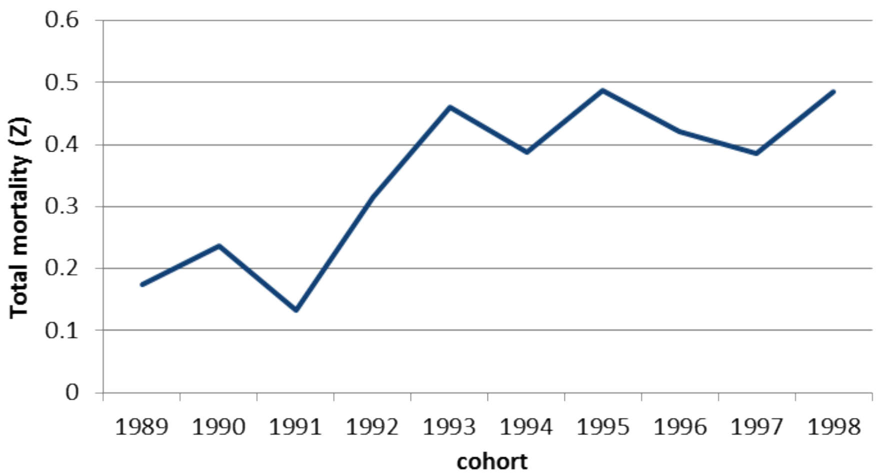

Figure 4.4.1.2. North Sea Horse Mackerel. Negative gradients of the 1989 – 1998 cohorts catch curves.

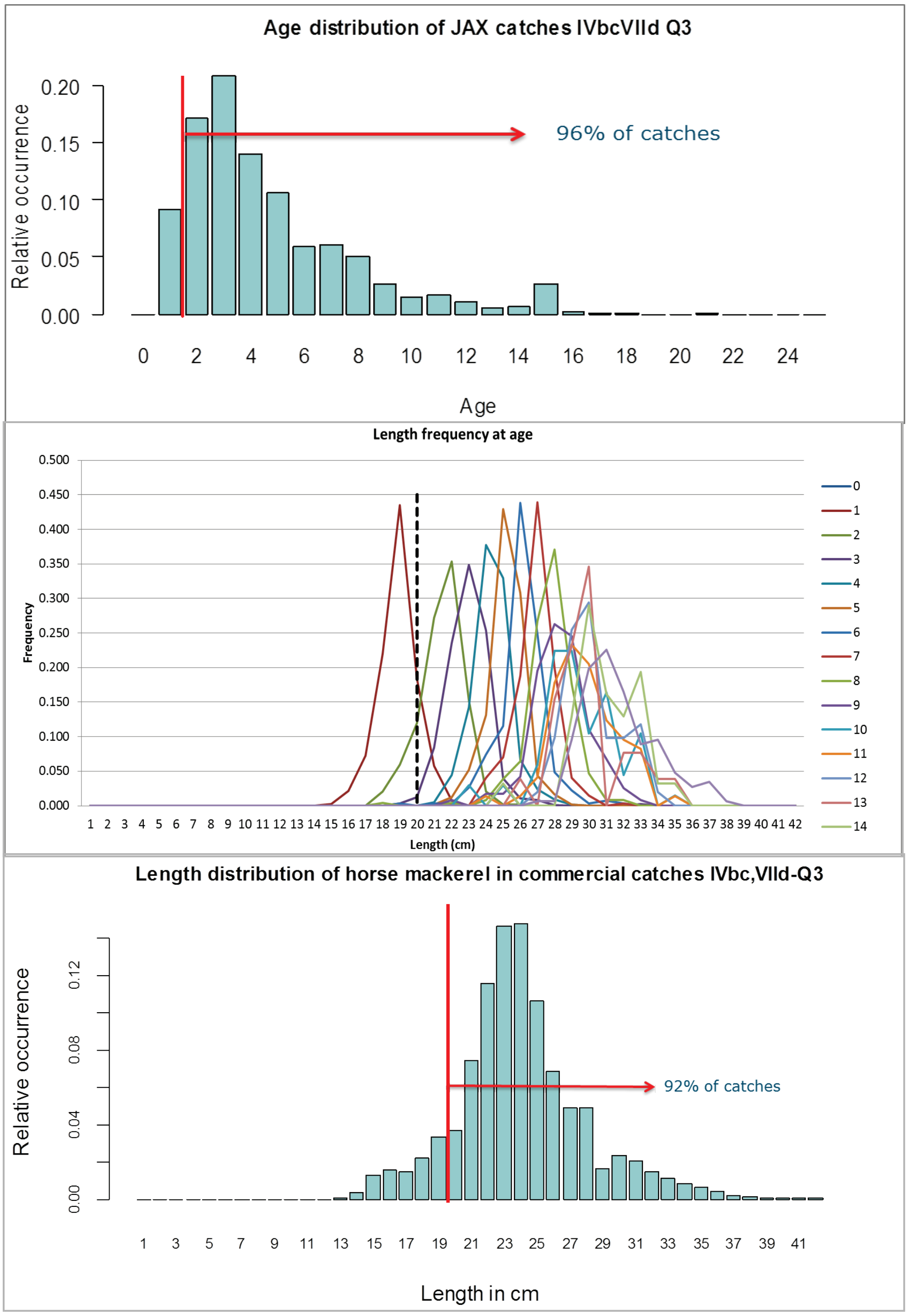

Figure 4.4.3.1 Age distribution of commercial catches in the 3rd quarter (top), length distribution at age in the third quarter (middle) and length distribution of commercial catches in the 3rd quarter (bottom).

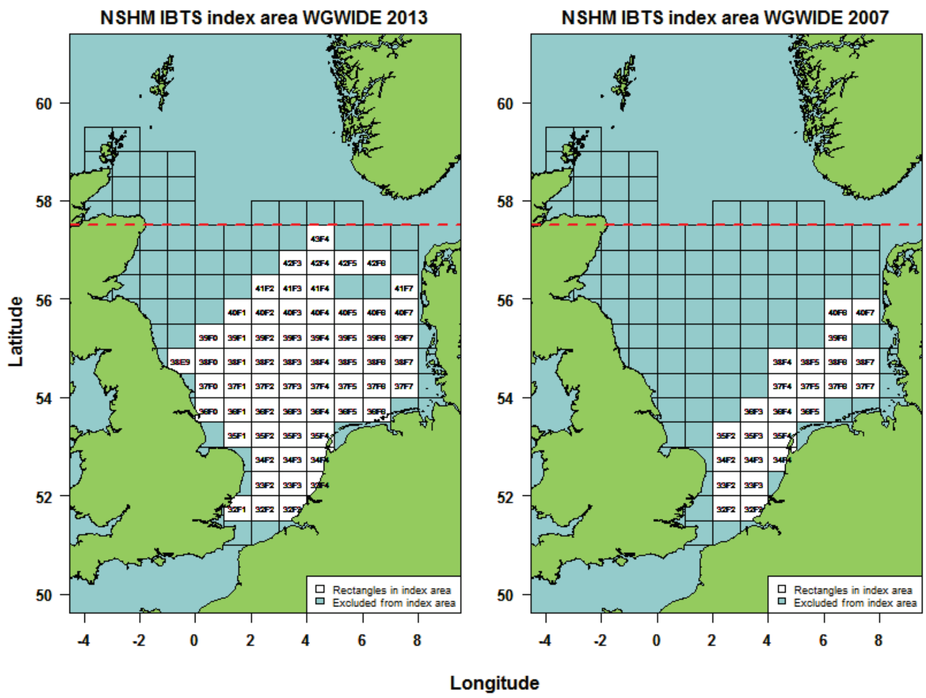

Figure 4.4.3.2 ICES rectangles selected in 2013 (left) compared to selection for explorations in previous years (right).

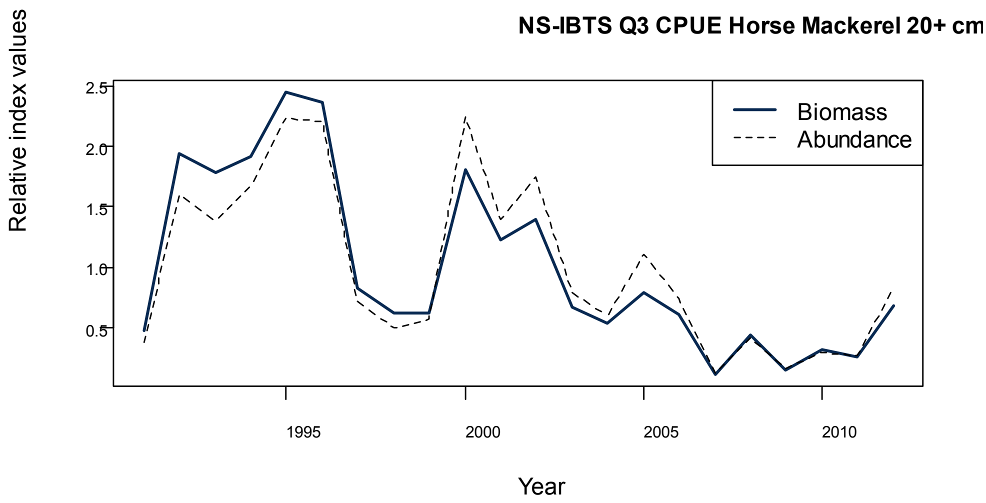

Figure 4.5.3.3 North Sea horse mackerel. IBTS Q3 biomass index versus cpue (nr/ hour) for length classes >=20 cm.

5 Western Horse Mackerel - Divisions IIa, IIIa (Western Part), IVa, Vb, VIa, VIIa-c, VIIe-k, AND VIIIa-e

5.1 ICES advice applicable to 2012 and 2013

EU has set TACs for western horse mackerel in EU waters since 1987. However, these TACs covered a mixture of western, North Sea and southern horse mackerel areas. Since 2011, the TACs cover areas more in line with the distribution areas of the stocks.

For 2012, the TACs can be summarised as follows (EC 44/2012):

Areas in EU waters	*TAC 2012*	Stocks fished in this area
IIa, IVa, Vb, Subareas VI,VIIa-c, VIIe-k, VIIIabde, Vb, XII, XIV	*157,989 t*	Western stock & North Sea stock in IVa 1-2 quarters
IVb,c, VIId	44,180 t	North Sea stocks
Division VIIIc and Subarea IX	25,011 t	Western stock

The TAC set in EU waters for 2013 (EC 39/2013):

Areas in EU waters	*TAC 2013*	Stocks fished in this area
IIa, IVa, Vb, Subareas VI,VIIa-c, VIIe-k, VIIIabde, Vb, XII, XIV	*157,989 t*	Western stock & North Sea stock in IVa 1-2 quarters
IVb,c, VIId	37,950 t	North Sea stocks
Division VIIIc	25,011 t	Western stock

The TAC for the western stock should apply to the distribution area of western horse mackerel as follows:

All Quarters: IIa, Vb, VIa, VIIa-c, VIIe-k, VIIIa-e
Quarters 3&4: IIIa (west), IVa

The TAC for the North Sea stock should apply to the distribution area of North Sea horse mackerel as follows:

All Quarters: IIIa (east), IVb-c, VIId
Quarters 1&2: IIIa (west), IVa

In 2007 ICES evaluated the proposed management plan for western horse mackerel to be in accordance with the precautionary approach and advised a TAC of 180,000 tons for each of the years 2008, 2009 and 2010. Following the proposed management plan and the EU policy paper on fisheries management (17 May 2010, COM(2010) 241) which classifies this stock under category 4 implies a TAC of 137,500 t in 2013. The TAC should apply to the total distribution area of this stock. The EU horse mackerel catches in Division IIIa are taken outside the horse mackerel TACs.

5.1.1 The fishery in 2012

Information on the development of the fisheries by quarter and division is shown in Table 3.1.2 and in Figures 3.1.1.a–d. The total catch allocated to western horse mackerel in 2013 was 173,142 t (Table 3.3.1) which is 26,450 t less than in 2011 and 47,100 t more than advised by ICES. The catches of horse mackerel by country and area are shown in Tables 5.1.1.1-5.

5.1.2 Estimates of discards

Over the years only Netherlands has provided data on discards and for a few years Germany has also provided such data. For 2012 there are also data from Spain, Germany, Netherlands and Ireland. Therefore, the amount of discards given in Table 3.3.1 are not representative of the total fishery. Based on the limited data available it is impossible to estimate the amount of discard in the horse mackerel fisheries (see section 1.3.3). Discards are used in the assessment when provided to the working group.

5.1.3 Stock description and management units

The western horse mackerel stock spawns in the Bay of Biscay, and in UK and Irish waters. After spawning, parts of the stock migrate northwards into the Norwegian Sea and the North Sea, where they are fished in the third and fourth quarter. The stock is distributed in Divisions IIa, Vb, IIIa, IVa, VIa, VIIa-c, VIIe-k and VIIIa-e. The stock is caught in these areas following the yearly distribution described in Section 3.3 (Figure 5.1.3.1). The western stock is considered a management unit and advised accordingly. At present there are no international agreed management measures, neither a TAC for western horse mackerel. EU regulates the fishery by TAC. For the first time in 2011 this TAC was almost set in accordance with the distribution of the stock (see section 5.1).

5.2 Scientific data

5.2.1 Egg survey estimates

In 2013 a new egg survey was carried out in the western and southern spawning areas and a working document with preliminary results of the survey was distributed to WGWIDE members (Burns *et al.* 2013). There were no amendments to the previous year's results. Details of this mackerel and horse mackerel egg survey are given in section 2.5.1 of this report.

Egg abundance plots displaying the spatial distribution of stage 1 western horse mackerel eggs are presented for periods 2 – 6 (Figures 5.2.1.1 – 5.2.1.5).

The mean daily stage I egg production estimates (DEP) for each survey period plotted against the mid-period days is shown in figure 5.2.1.6. The results from previous surveys are also included in the figure for comparison. Period number and duration are the same as those used to estimate the western mackerel stock, as are the dates defining the start and end of spawning. The shape of the egg production curve does not suggest that those dates should be altered for 2013, although, it seems likely that some spawning continued after the survey ended. The daily egg production curve revealed a provisional estimate of total annual egg production of 3.95×10^{14}. This is about a 64% decrease on that observed in 2010 (1.09×10^{15}) and is one of the lowest estimates of annual egg production ever recorded for this species.

5.2.2 Other surveys for western horse mackerel

Bottom trawl surveys

No new information was presented on bottom trawl surveys. These surveys could be considered in future to provide indices of recruitment or abundance for western horse mackerel. Further information can be found in the stock annex, and in ICES (2008/ACOM:13) and ICES (2009/RMC:04).

Acoustic surveys

No new information was presented on acoustic surveys. Further information can be found in the stock annex and in ICES (2008/ACOM:13) and ICES (2006/LRC:18).

5.2.3 Effort and catch per unit effort

No new information was presented on effort and catch per unit effort. Further information can be found in the stock annex.

5.2.4 Catch in numbers

In 2012, the Netherlands (IVa,VIa,VIIb,c,e,h-k), Norway (IVa), Ireland (VIa and VIIb, j), Germany (VIIb,e,h), Spain (VIIIb,c) and UK(England) (VIIe,j) provided catch in numbers at age. The catch sampled for age readings in 2012 covered 71% compared to 62% in 2011 and 78% in 2010.

The total annual and quarterly catches in numbers for western horse mackerel in 2012 are shown in Table 5.2.4.1. The sampling intensity is discussed in Section 1.3.

The catch at age matrix, as used in the assessment, is given in Table 5.2.4.2, and illustrated in Figure 5.2.4.1. It shows the dominance of the 1982 year class in the catches since 1984 until it entered the plus group in 1996. Since 2002 the 2001 year class of horse mackerel which has now entered the plus group in 2012, has been caught in considerable numbers.

5.2.5 Mean length at age and mean weight at age

Mean length at age and mean weight at age in the catches

The mean weight and mean length at age in the catches by area, and by quarter in 2012 are shown in Tables 5.2.5.1 and 5.2.5.2. Weight at age time-series is shown in Figure 5.2.5.1.

Mean weight at age in the stock

Mean weights-at-age in the stock, as used in the assessment, are presented in Table 5.2.5.3. Weight has been estimated for age two in 2012 as there were no weight samples available for this age group. Weight at age time-series is shown in Figure 5.2.5.2. Further information can be found in the stock annex.

5.2.6 Maturity ogive

Maturity-at-age, as used in the assessment, is presented in Table 5.2.6.1. Further information can be found in the stock annex.

5.2.7 Natural mortality

A fixed natural mortality of 0.15.year^{-1} is assumed for all ages and years in the assessment. Further information can be found in the stock annex.

5.2.8 Fecundity data

The potential fecundity data used in the assessment is listed in Table 5.2.8.1. The basis for specifying the realised fecundity 'prior', as used in the assessment (mean=1 847 eggs per gram spawning female, CV=0.287), is given in the stock annex.

5.2.9 Data exploration

Within-cohort consistency of the catch-at-age matrix is investigated in Figure 5.2.9.1, and demonstrates that the catch-at-age data contains information on year class strength that could form the basis for an age-structured model.

Log-catch curves are shown in Figure 5.2.9.2, along with the negative of the gradients fitted to ages 1-3 (bottom left plot), and ages 4-8 (bottom right plot). The general pattern of log-catches is increasing log-catch with age for the earlier years, indicating cohorts are not fully selected until they have reached an advanced age, and the more usual decreasing log-catch for a wider range of ages in the most recent years (compared to earlier years), indicating selection has shifted towards younger fish over time. A requirement for interpreting the negative gradient as a proxy for total mortality is that catchability and selectivity-at-age remains stable within a cohort, so that any changes in the catch of a cohort are explained by changes in total mortality. The prevalence of negative values for the proxy (bottom plots of Figure 5.2.9.2) indicates that this requirement has not always been met for western horse mackerel catch data, and also indicates that a separable model with constant selectivity-at-age for the earliest data would not be appropriate.

5.2.10 Assessment model

The SAD (linked Separable-ADAPT VPA) model is used for the assessment of western horse mackerel. A description of the model can be found in the stock annex. The western horse mackerel assessment is presented as an update assessment and was conducted with a 6-year window as in the previous assessment carried out in 2012.

Fits to the available data are given in Figure 5.2.10.1, and model estimates with associated precision in Figures 5.2.10.2-3. Model estimates and residual patterns are similar to those presented in 2012 (ICES 2012/ACOM:15). A comparison with the 2012 assessment is discussed in Section 5.6.

Retrospective plots are shown for two cases. In the first case, 6-year retrospective plots were constructed for SSB, recruitment and F trajectories, and for selectivity-at-age, where the length of the separable window is kept at six years (Figure 5.2.10.4.) Substantial retrospective bias both in the recent period and historically, resulting in overestimation of SSB and recruitment and underestimation of F for the most recent years of the annual assessments. This behaviour is likely due to the changes in selectivity-at-age for the separable period as the window is moved back in time which may invalidate the separable assumption. In addition, the exclusion of the egg production data as the retrospective analysis is carried out has an effect back in the time-series estimates (not only for this set of retrospective plots, but for the one discussed below).

For the second case, 3-year retrospective plots were constructed as before, but this time the starting year of the separable window (2007) was kept constant, thus resulting in the separable window reducing in length as years were dropped. The reduced length of the separable window only allowed 3 years for the analysis, because a window any shorter than 3 years in length results in a large deterioration in the precision of model estimates. Results for the second set of retrospective plots are shown in Figure 5.2.10.5. The estimates of selectivity-at-age in Figure 5.2.10.5d were different for both retrospective assessments compared to the final assessment and the assessment with the recent egg survey estimate removed, this is largely due to the shortening of the separable window, causing greater uncertainty and deterioration in the precision of the model estimates, particularly for the younger age groups.

5.3 State of the Stock

5.3.1 Stock assessment

The SAD model with a separable window of 2007-2012 is presented as the final assessment model. Stock numbers-at-age and fishing mortality-at-age are given in Tables 5.3.1.1 and 5.3.1.2, and a stock-summary is provided in Table 5.3.1.3, and illustrated in Figure 5.3.1.1. SSB peaked in 1988 following the very strong 1982 year class. Subsequently SSB peaked following the moderate year classes in the early- to mid-90s and the moderate-to-strong year class of 2001 (a third of the size of the 1982 year class). Year classes following 2001 have been weak, 2010 recruitment in particular is the lowest in the time-series. Fishing mortality has been increasing since 2007 as a result of increasing catches and decreasing biomass as the 2001 year-class is reduced.

5.4 Short-term forecast

A deterministic short-term forecast was conducted with the ICES standard software MFDP (Multi Fleet Deterministic Projection) version 1a.

Input

Table 5.4.1 lists the input data for the short term predictions. Weight at age in the stock and weight at age in the catch are the average of the 2010 to 2012. Selection (exploitation pattern is based on F in 2012 from the most recent assessment and is the average of ages 1 to 10, which assumes a fixed selection in the period 2007-2012. Natural mortality is assumed to be 0.15 across all ages. The proportion mature for this stock has been constant since 1998 and values are copied from the assessment input.

As with last year the expected landings for the intermediate year were set to the level that would follow from the application of the management plan, 183kt. This coincides with 2013 TAC and is considered to be an appropriate estimate for the forecast.

Output

Detailed age disaggregated tables for an F status quo projection are shown in Table 5.4.2 and a range of predicted catch and SSB options from the short term forecast are presented in Table 5.4.3. Table 5.4.4 details the forecast results for various management options and levels of F in relation to status quo.

The management plan proposed by the Pelagic RAC in 2007 was recently evaluated (ICES 2013/ACOM:59) and as a consequence of the deficiencies found, ICES considered that the HCR and reference points in its original form is not consistent with the precautionary approach.

In the absence of any new precautionary biomass reference points, relative biomass reference points were calculated using the latest assessment outputs to assess the position of the terminal year.

Relative reference point	B_{lim}	B_{pa}	F_{lim}	F_{pa}	$F_{0.1}$
Value	655 thousand t	949 thousand t			0.13
Basis	Lowest estimated biomass of the 2013 assessment	$\mathbf{B}_{lim}$* exp(1.645* σ), with σ= 0.23.	Not defined	Not defined	Yield per recruit (ICES, 2010/ACOM:15)

Given that the 2013 biomass has been estimated to be below the relative $B_{trigger}$, following the ICES MSY approach implies fishing mortality = $F_{MSY} x SSB_{2014}/B_{rtinger}$ = 0.10 resulting in catches of 88 508 tonnes in 2014. This is expected to lead to an SSB of 573 686 tonnes in 2015.

5.5 Uncertainties in the assessment and forecast

Fishery-independent data for this stock is extremely limited, with only a single data point for egg production every three years. In addition, the assessment contains a fecundity model which links the egg production to SSB that could be improved if further evidence was obtained on the spawning biology of this stock which at present is considered an indeterminate spawner.

The reliability of this assessment depends on the reliability of the input data, and the extent to which model assumptions are violated. For example, simulation testing has shown that if there is an increasing trend in the realised fecundity parameter that is not accounted for, then the model over-estimates SSB and recruitment, and underestimates fishing mortality and realised fecundity (ICES 2008/ACOM:13).

The model relies on a 'prior' distribution for realised fecundity (based on published values), which is used for scaling, and the inclusion of any additional information on realised fecundity would help to improve the reliability of the assessment. Estimates of F are considerably lower than the assumed value for natural mortality (M=0.15). Reviewers have commented that the assumed value for M should be investigated. However, there is no data available (such as tagging) that could assist in estimating M more accurately. Nevertheless, total mortality appears to be low, given the persistence of the 1982 year class in the catch data.

Decisions on the length of the separable window need to balance the precision of model estimates (windows that are too short result in less precise model estimates) with considerations of whether the separability assumption continues to hold (by considering information from the fishery and patterns in the log-catch residual plots).

Although some estimates on the uncertainty of the egg input data are available, they are not currently available in a form that can be included in the assessment model. This is one area that might need addressing in the future if a systematic estimation of likely error in the model is to be evaluated. The inclusion of independent estimates of the uncertainty of the egg production would improve the reliability of the assessment.

The precision of recruitment estimates for the most recent years is poor, with CVs of 29-56% for the most recent 5 years. This result is expected given the negligible input the first three age classes make to SSB and the limited catch data for recruits. This uncertainty increases as the assessment is updated without additional egg production survey data. The estimate for the 2001 year class at age 0 is the largest since 1982, with a CV of 21%.

The assessment could be improved by the inclusion of information such as survey tuning indices on the numbers at age in the stock. However, obtaining a reliable tuning series is likely to be hampered by the large geographic area in which the stock occurs and the strong migration patterns. It does not seem that changes to the modelling methodology alone will fundamentally solve this problem.

5.6 Comparison with previous assessment and forecast

A comparison of the update assessment with the 2012 assessment is shown in Figure 5.6.1. SSB, recruitment and F trajectories show a similar pattern but have been reduced by the incorporation of the new 2013 provisional egg estimate. The large decrease in selectivity for younger age groups, particularly for the 1 year olds (see Figure 5.6.1), is largely due to the lack of information on these age groups which causes instability in the estimated selection pattern.

5.7 Management Options

5.7.1 MSY approach

In 2013 deterministic and stochastic equilibrium analyses were carried out using the 'plotMSY' software (WKFRAME 2010) to re-evaluate the 2010 Fmsy value for the western horse mackerel stock. With the inclusion of the most recent data the results, similar to those provided in 2010, suggest that the F_{msy} proxy of 0.13 remains valid. See WGWIDE 2011 for details, or refer to the stock annex.

5.7.2 Management plans and evaluations

In 2007 the Pelagic RAC, in collaboration with a group of scientists, developed and proposed a management plan for the Western Horse Mackerel stock. The plan sets a multiannual TAC using a harvest rule that comprises a fixed TAC component and one that varies with the trend in egg production as recorded during the previous 3 egg surveys. The TAC is set according to the following rule:

$$TAC_{y+1 \text{ to } y+3} = 1.07\left[\frac{TAC_{ref}}{2} + \frac{TAC_{y-2 \text{ to } y}sl}{2}\right]$$

where y is the year an egg survey becomes available, TAC_{ref} = 150kt and sl is a function of the slope of the most recent three egg abundance estimates from surveys such that

	slope	≤ -1.5	sl = 0
-1.5 <	slope	< 0	sl = 1-((1/-1.5)*slope)
0 ≤	slope	≤ 0.5	sl = 1+((0.4/0.5)*slope)
0.5 >	slope		sl = 1.4

Upon evaluation, ICES considered the plan to be precautionary only in the short term (3 years). The plan was used in the setting of the TAC for the three year period 2011-2012 at 183kt, using the egg survey result of 2010. This year, the provisional egg survey estimate for 2013 has been applied, resulting in a TAC for 2014-2016 of 137 524t.

Although in use for the purposes of setting the TAC, there are several issues related to the implementation of the management plan. The plan has not yet been officially placed into EC regulations as aspects remain under negotiation and the legal structure of the plan is adapted to account for changes under the Lisbon treaty. Aspects of the proposed plan currently under discussion include the realignment of the assessment and management areas for the stock (which has been highlighted for several years as problematic in terms of the management of the fishery) and an annual TAC adjustment to account for estimated discards and slipping in the previous year. The regulation also proposes a formal review of the plan in 2014.

5.8 Management considerations

The 2001 year class has now entered the plus group and there are no detectable strong year classes entering the fishery. This year, a preliminary egg abundance estimate is available from the 2013 egg survey. This data point has been included in the assessment with the catch data from 2012. With the inclusion of the new 2013 egg survey estimate the perception of the stock as changed. However the declining trend in SSB and upward trajectory of F_{1-10} remains the same.

SSB in 2013 was estimated at 0.84Mt, this is below the 1982 SSB of 1.4Mt which was previously adopted as B_{lim}. A B_{pa} consistent with this is 1.8Mt and was proposed in 2008. However, B_{pa} is not used as a reference for management but rather the rule in the agreed management plan is used. There are currently no accepted biomass reference points for this stock following the revision of the assessment methodology and acceptance of the assessment in 2011.

The TAC has only been given for parts of the distribution and fishing areas (EU waters). The Working Group advises that the TAC should apply to all areas where western horse mackerel are caught. Note that sub-area VIIIc is now included in the Western stock distribution area. If (as planned) the management area limits are revised, measures should be taken to ensure that misreporting of juvenile catch taken in sub-areas VIIe,h and VIId (the latter then belonging to the North Sea stock management area) is effectively hindered. The mismatch between TAC and fishing areas and the fact that the TAC is only applied to EU waters has resulted in the catch prior to 2007 exceeding those advised by ICES.

The management plan proposed by the Pelagic RAC in 2007 was evaluated by ICES and considered to be precautionary in the short term. This plan makes use of the information available in the egg production surveys, and bases triennial TACs on the slope of the three previous egg production estimates. The rule proposed by the plan was used to set the TAC for 2008-2010 at 180kt and 2011-2013 at 183kt. Using the finalised 2007 and 2010 egg survey results and the preliminary 2013 egg survey result the catch advice for 2014-2016 is 137 534t. It should be noted that the management plan assumes that all catches are taken against the TAC and, should the management and assessment areas be combined in the future, the TAC as set by the EU will not cover all fisheries.

5.9 Ecosystem considerations

Knowledge about the distribution of the western horse mackerel stock is gained from the egg surveys and the seasonal changes in the fishery. However, based on these observations it is not possible to infer a similar changing trend in the distribution of western horse mackerel as for NEA mackerel.

5.10 Regulations and their effects

There are no horse mackerel management agreements between EU and non EU countries. The TAC set by EU therefore only apply to EU waters and the EU fleet in international waters. The minimum landing size of horse mackerel by the EU fleet is 15cm (10% undersized allowed in the catches).

The stock allocations were changed in 2005 following the results of the HOMSIR project (Abaunza *et al*. 2003) and VIIIc now belongs to the western stock.

In Norwegian waters there is no quota for horse mackerel but existing regulations on bycatch proportions as well as a general discard prohibition (for all species) apply to horse mackerel.

5.11 Changes in fishing technology and fishing patterns

The description of the fishery is given in Sections 3.1 and 5.2.1 and no large changes in fishing areas or patterns have taken place. However, there has been a gradual shift from an industrial fishery for meal and oil towards a human consumption fishery.

5.12 Changes in the environment

Migrations are closely associated with the slope current, and horse mackerel migrations are known to be modulated by temperature. Continued warming of the slope current is likely to affect the timing and spatial extent of this migration.

Since the strong 1982 year class of the western stock started to appear in the North Sea in 1987 a good correspondence between the modelled influx of Atlantic water to the North Sea in the first quarter and the horse mackerel catches taken by Norwegian purse seiners in the Norwegian EEZ (NEZ) later (October-November) the same year (Iversen *et al*. 2002, Iversen WD presented in ICES 2007/ACFM:31) has been noted in most years.

5.13 References

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Table 5.1.1.1. Horse mackerel general. Catches (t) in Subarea II. (Data as submitted by Working Group members).

Country	1980	1981	1982	1983	1984	1985	1986	1987
Denmark	-	-	-	-	-	-	-	39
France	-	-	-	-	1	1	-[2]	-[2]
Germany, Fed.Rep	-	+	-	-	-	-	-	-
Norway	-	-	-	412	22	78	214	3,272
USSR	-	-	-	-	-	-	-	-
Total	-	+	-	412	23	79	214	3,311

	1988	1989	1990	1991	1992	1993	1994	1995
Faroe Islands	-	-	9643	1,115	9,157[3]	1,068	-	950
Denmark	-	-	-	-	-	-	-	200
France	-2	-	-	-	-	-	55	-
Germany, Fed. Rep.	64	12	+	-	-	-	-	-
Norway	6,285	4,770	9,135	3,200	4,300	2,100	4	11,300
USSR / Russia (1992 -)	469	27	1,298	172	-	-	700	1,633
UK (England + Wales)	-	-	17		-	-	-	-
Total	6,818	4,809	11,414	4,487	13,457	3,168	759	14,083

	1996	1997	1998	1999	2000	2001	2002	2003
Faroe Islands	1,598	799[3]	188[3]	132[3]	250[3]	-	-	-
Denmark	-	-	1,755[3]	-		-	-	-
France	-	-	-	-		-	-	-
Germany	-	-	-	-		-	-	-
Norway	887	1,170	234	2,304	841	44	1,321	22
Russia	881	648	345	121	84[3]	16	3	2
UK (England + Wales)	-	-	-	-	-	-	-	-
Estonia	-	-	22	-	-	-	-	-
Total	3,366	2,617	2,544	2557	1175	60	1,324	24

	2004	2005	2006	2007	2008	2009	2010[1]
Faroe Islands	-	-	3	-	-	-	2923[3]
Denmark	-	-	-	-	-	-	-
France	-	-	-	-	-	-	-
Germany	-	-	-	-	-	-	-
Ireland	-	-	-	366[4]	-	-	-
Norway	42	176	27	-	572	1,847	1,364
Russia	-	-	-	-	-	-	-
UK (England + Wales)	-	-	-	-	-	-	-
Estonia	-	-	-	-	-	-	-
Total	42	176	30	366	572	1,847	1,656

[1]Preliminary.
[2]Included in Subarea IV.
[3]Includes catches in Div. Vb.
[4]Taken in Div. Vb

Table 5.1.1.1 cont. Horse mackerel general. Catches (t) in Subarea II. (Data as submitted by Working Group members).

	2011	2012
Faroe Islands	349[4]	-
Denmark	-	-
France	-	+
Germany	-	-
Ireland	-	
Netherlands	1	-
Norway	298	66
Russia	-	-
UK (England + Wales)	-	-
Estonia	-	-
Total	648	66

[1]Preliminary
[2]Included in IV.
[3]Includes catches in Div. Vb.
[4]Taken in Div. Vb.

Table 5.1.1.2. Horse mackerel general. Catches (t) in North Sea Subarea IV and Skagerrak Division IIIa by country. (Data submitted by Working Group members). Catches partly concern the North Sea horse mackerel.

Country	1980	1981	1982	1983	1984	1985	1986	1987	1988
Belgium	8	34	7	55	20	13	13	9	10
Denmark	199	3,576	1,612	1,590	23,730	22,495	18,652	7,290	20,323
Faroe Islands	260	-	-	-	-	-	-	-	-
France	292	421	567	366	827	298	231[2]	189[2]	784[2]
Germany, Fed.Rep.	+	139	30	52	+	+	-	3	153
Ireland	1,161	412	-	-	-	-	-	-	-
Netherlands	101	355	559	2,029[3]	824	160[3]	600[3]	850[4]	1,060[3]
Norway[2]	119	2,292	7	322	[3]	203	776	11,728[4]	34,425[4]
Poland	-	-	-	2	94	-	-	-	-
Sweden	-	-	-	-	-	-	2	-	-
UK (Engl. + Wales)	11	15	6	4	-	71	3	339	373
UK (Scotland)	-	-	-	-	3	998	531	487	5,749
USSR	-	-	-	-	489	-	-	-	-
Total	2,151	7,253	2,788	4,420	25,987	24,238	20,808	20,895	62,877

Country	1989	1990	1991	1992	1993	1994	1995	1996	1997
Belgium	10	13	-	+	74	57	51	28	-
Denmark	23,329	20,605	6,982	7,755	6,120	3,921	2,432	1,433	648
Estonia	-	-	-	293	-		17	-	-
Faroe Islands	-	942	340	-	360	275	-	-	296
France	248	220	174	162	302		-	-	-
Germany, Fed.Rep.	506	2,469[5]	5,995	2,801	1,570	1,014	1,600	7	7,603
Ireland	-	687	2,657	2,600	4,086	415	220	1,100	8,152
Netherlands	14,172	1,970	3,852	3,000	2,470	1,329	5,285	6,205	37,778
Norway	84,161	117,903	50,000	96,000	126,800	94,000	84,747	14,639	45,314
Poland	-	-	-	-	-	-	-	-	-
Sweden	-	102	953	800	697	2,087	-	95	232
UK (Engl. + Wales)	10	10	132	4	115	389	478	40	242
UK (N. Ireland)	-	-	350	-	-		-	-	-
UK (Scotland)	2,093	458	7,309	996	1,059	7,582	3,650	2,442	10,511
USSR / Russia (1992 -)	-	-	-						
Unallocated + discards	12,482[4]	-317[4]	-750[4]	-278[6]	-3,270	1,511	-28	136	-31,615
Total	112,047	145,062	77,904	114,133	140,383	112,580	98,452	26,125	79,161

Country	1998	1999	2000	2001	2002	2003	2004	2005	2006[1]
Belgium	19	21	19	19	1,004	5	4	6	3
Denmark	2,048	8,006	4,409	2,288	1,393	3,774	8,735	4,258	1,343
Estonia	22	-	-						
Faroe Islands	28	908	24	-	699	809		35	
France	379	60	49	48	-	392	174	3,876	2,380
Germany	4,620	4,071	3,115	230	2,671	3,048	4,905	1,811	965
Ireland	-	404	103	375	72	93	379	753	2,077
Lithuania									2,354
Netherlands	3,811	3,610	3,382	4,685	6,612	17,354	21,418	24,679	20,984
Norway	13,129	44,344	1,246	7,948	35,368	20,493	10,709	24,937	27,200
Russia	-	-	2	-	-	-			
Sweden	3,411	1,957	1,141	119	575	1,074	665	239	491
UK (Engl. + Wales)	2	11	15	317	1,191	1,192	2,552	1,778	423
UK (Scotland)	3,041	1,658	3,465	3,161	255	1	1	22	
Unallocated+discards	737	-325	14613	649	-149	-14,009	-19,103	-21,830	314
									-19,623
Total	31,247	64,725	31583	19,839	49,691	34,226	30,435	40,564	38,911

[1]-Preliminary. [2] Includes Division IIa. [3] Estimated from biological sampling. [4] Assumed to be misreported. [5] Includes 13 t from the German Democratic Republic. [6] Includes a negative unallocated catch of -4,000 t.

Table 5.1.1.2 cont. Horse mackerel general. Catches (t) in North Sea Subarea IV and Skagerrak Division IIIa by country. (Data submitted by Working Group members). Catches partly concern the North Sea horse mackerel.

Country	2007	2008	2009	2010	2011	2012[1]
Belgium	5	2	4	12	-	-
Denmark	329	59	279	75	20	9
Faroe Islands	3	55	-	81	-	-
France	457	943	-	173	268[2]	
Germany, Fed.Rep.	93	1,167	1,299	242	-	--
Ireland	652	1,186	342	12	755	25
Netherlands	20,027	9,400	10,077	1,342	81	92
Lithuania	98	-	-	-	-	-
Norway	5.423	11652	70,745	11,082	13,409	3,183
Sweden	130	45	660	2	90	-
UK (Engl. + Wales)	2,966	-	-	-	-	-
UK (Scotland)	626	20	51	646	101	12
Unallocated +discards	- 14,403	-9,151	-5,898	0	-	-
Total	16,407	15,377	78,595	13,667	14,725	3,321

[1]-Preliminary.

[2]French catches landed in the Netherlands

Table 5.1.1.3 Horse mackerel general. Catches (t) in Subarea VI by country. (Data submitted by Working Group members).

Country	1980	1981	1982	1983	1984	1985	1986	1987	1988
Denmark	734	341	2,785	7	-	-	-	769	1,655
Faroe Islands	-	-	1,248	-	-	4,014	1,992	4,450[3]	4,000[3]
France	45	454	4	10	14	13	12	20	10
Germany, Fed. Rep.	5,550	10,212	2,113	4,146	130	191	354	174	615
Ireland	-	-	-	15,086	13,858	27,102	28,125	29,743	27,872
Netherlands	2,385	100	50	94	17,500	18,450	3,450	5,750	3,340
Norway	-	5	-	-	-		83	75	41
Spain	-	-	-	-	-		-[2]	-[2]	-[2]
UK (Engl. + Wales)	9	5	+	38	+	996	198	404	475
UK (N. Ireland)						-	-	-	-
UK (Scotland)	1	17	83	-	214	1,427	138	1,027	7,834
USSR.	-	-	-		-	-	-	-	-
Unallocated + disc						-19,168	-13,897	-7,255	-
Total	8,724	11,134	6,283	19,381	31,716	33,025	20,455	35,157	45,842

Country	1989	1990	1991	1992	1993	1994	1995	1996	1997
Denmark	973	615	-	42	-	294	106	114	780
Faroe Islands	3,059	628	255	-	820	80	-	-	-
France	2	17	4	3	+	-	-	-	52
Germany, Fed. Rep.	1,162	2,474	2,500	6,281	10,023	1,430	1,368	943	229
Ireland	19,493	15,911	24,766	32,994	44,802	65,564	120,124	87,872	22,474
Netherlands	1,907	660	3,369	2,150	590	341	2,326	572	498
Norway	-	-	-	-	-	-	-	-	-
Spain	-[2]	-[2]	1	3	-	-	-	-	-
UK (Engl. + Wales)	44	145	1,229	577	144	109	208	612	56
UK (N.Ireland)	-	-	1,970	273	-	-	-	-	767
UK (Scotland)	1,737	267	1,640	86	4,523	1,760	789	2,669	14,452
USSR/Russia (1992-)	-	44	-	-	-	-	-	-	-
Unallocated + disc.	6,493	143	-1,278	-1,940	-6,960[4]	-51	-41,326	-11,523	837
Total	34,870	20,904	34,456	40,469	53,942	69,527	83,595	81,259	40,145

Country	1998	1999	2000	2001	2002	2003	2004	2005	2006
Denmark	-	-	-	-	-	-	-	-	-
Faroe Islands	-	-	-	-	-	-	-	-	-
France	221	25,007	-	428	55	209	172	41	411
Germany	414	1,031	209	265	149	1,337	1,413	1,958	1,025
Ireland	21,608	31,736	15,843	20,162	12,341	20,915	15,702	12,395	9,780
Lithuania									2,822
Netherlands	885	1,139	687	600	450	847	3,701	6,039	1,892
Spain	-	-	-	-	-	-	-	-	-
UK (Engl.+Wales)	10	344	41	91	-	46	5	52	-
UK (N.Ireland)	1,132	-	-			453		210	82
UK (Scotland)	10,447	4,544	1,839	3,111	1,192		377	62	43
Unallocated+disc.	98	1,507	2,038	-21	3	-553	559	1,298	-304
Total	34,815	65,308	20,657	24,636	14,190	23,254	21,929	22,055	15,751

Table 5.1.1.3. cont. Horse mackerel general. Catches (t) in Subarea VI by country. (Data submitted by Working Group members).

Country	2007	2008	2009	2010	2011	2012[1]
Denmark	-	-	-	-	58	1131
Faroe Islands	-	573	-	1	-	-
France	-	74	-	-	246[5]	-
Germany	1,835	5,097	635	773	6,508	672
Ireland	20,341	18,786	16,565	19,985	23,556	29,283
Lithuania	80	641	-	-	-	-
Netherlands	2,177	3,904	2,332	1,685	6,353	12,653
Norway	2	20	27	18	48	2
Russia	-	-	-	-	-	-
Spain	-	-	-	-	-	-
UK (Engl. + Wales)	232	-	-	-	-	-
UK (Scotland)	38	588	243	89	2,528	1,232
Unallocated+disc.	1,474	-3,781	-2,057	62	230	2
Total	26,279	25,902	17,776	22,613	39,528	44,975

[1]Preliminary. [2]Included in Subarea VII. [3]Includes Divisions IIIa, IVa,b and VIb.

[4]Includes a negative unallocated catch of -7000 t. [5]French catches landed in the Netherlands

Table 5.1.1.4. Horse mackerel general . Catches (t) in Subarea VII by country. (Data submitted by the Working Group members).

Country	1980	1981	1982	1983	1984	1985	1986	1987	1988
Belgium	-	1	1	-	-	+	+	2	-
Denmark	5,045	3,099	877	993	732	1,477[2]	30,408[2]	27,368	33,202
France	1,983	2,800	2,314	1,834	2,387	1,881	3,801	2,197	1,523
Germany, Fed.Rep.	2,289	1,079	12	1,977	228	-	5	374	4,705
Ireland	-	16	-	-	65	100	703	15	481
Netherlands	23,002	25,000	27,500[2]	34,350	38,700	33,550	40,750	69,400	43,560
Norway	394	-	-	-	-	-	-	-	-
Spain	50	234	104	142	560	275	137	148	150
UK (Engl. + Wales)	12,933	2,520	2,670	1,230	279	1,630	1,824	1,228	3,759
UK (Scotland)	1	-	-	-	1	1	+	2	2,873
USSR	-	-	-	-	-	120	-	-	-
Total	45,697	34,749	33,478	40,526	42,952	39,034	77,628	100,734	90,253

Country	1989	1990	1991	1992	1993	1994	1995	1996	1997
Faroe Islands	-	28	-	-	-	-	-	-	-
Belgium	-	+	-	-	-	1	-	-	18
Denmark	34,474	30,594	28,888	18,984	16,978	41,605	28,300	43,330	60,412
France	4,576	2,538	1,230	1,198	1,001	-	-	-	27,201
Germany, Fed.Rep.	7,743	8,109	12,919	12,951	15,684	14,828	17,436	15,949	28,549
Ireland	12,645	17,887	19,074	15,568	16,363	15,281	58,011	38,455	43,624
Netherlands	43,582	111,900	104,107	109,197	157,110	92,903	116,126	114,692	81,464
Norway	-	-	-	-	-	-	-	-	-
Spain	14	16	113	106	54	29	25	33	-
UK (Engl. + Wales)	4,488	13,371	6,436	7,870	6,090	12,418	31,641	28,605	17,464
UK (N.Ireland)	-	-	2,026	1,690	587	119	-	-	1,093
UK (Scotland)	+	139	1,992	5,008	3,123	9,015	10,522	11,241	7,931
USSR / Russia (1992-)	-	-	-	-	-	-	-	-	-
Unallocated + discards	28,368	7,614	24,541	15,563	4,010[3]	14,057	68,644	26,795	58,718
Total	135,890	192,196	201,326	188,135	221,000	200,256	330,705	279,100	326,474

Country	1998	1999	2000	2001	2002	2003	2004	2005	2006
Faroe Islands	-	-	550	-	-	-	-	3,660	1,201
Belgium	18	-	-	-	1	-	+	+	+
Denmark	25,492	19,223	13,946	20,574	10,094	10,867	11,529	9,939	6,838
France	24,223	-	20,401	11,049	6,466	7,199	8,083	8,469	7,928
Germany	25,414	15,247	9,692	8,320	10,812	13,873	16,352	10,437	7,139
Ireland	51,720	25,843	32,999	30,192	23,366	13,533	8,470	20,406	16,841
Lithuania									3,569
Netherlands	91,946	56,223	50,120	46,196	37,605	48.222	41,123	31,156	35,467
Spain	-	-	50	7	0	1	27	12	60
UK (Engl. + Wales)	12,832	8,885	2,972	8,901	5,525	4,186	7,178	4,752	2,935
UK (N.Ireland)	-	-	-	-	-			217	142
UK (Scotland)	5,095	4,994	5,152	1,757	1,461	268	1,146	59	413
Unallocated+discards	12,706	31,239	1,884	11,046	2,576	24,897	18,485	18,368	19,379
Total	249,446	161,654	137,766	138,042	97,906	123,046	112,393	107,475	101,912

Table 5.1.1.4. cont. Horse mackerel general . Catches (t) in Subarea VII by country. (Data submitted by the Working Group members).

Country	2007	2008	2009	2010	2011	2012[1]
Faroe Islands	475	212	-	-	-	-
Belgium	+	+	1	24	2	+
Denmark	4,806	1,970	2,710	5,247	5,831	2,281
France	6,844	11,008	-	899	7431[2]	579
Germany	3.943	5,700	14,204	20,404	14,545	16,391
Ireland	8,039	16,293	23,841	24,490	14,154	15,893
Lithuania	5,585	4,907	-	-	-	-
Netherlands	38,034	43,514	47,741	75,475	49,207	53,644
Norway	-	-	-	40	-	-
Spain	-	11	6	6	-	58
Sweden	55	-	-	-	-	-
UK (Engl. + Wales)	9,105	-	-	-	11,688	12,122
UK (Scotland)	738	476	1,123	1,723	299	91
Unallocated+discards	15,460	14,656	-61	17,534	-	3039
Total	93,084	98,746	89,565	145,839	103,156	104,098

[1]Preliminary. [2]French catches landed in the Netherlands

Table 5.1.1.5. Horse mackerel general. Catches (t) in Subarea VIII by country. (Data submitted by Working Group members).

Country	1980	1981	1982	1983	1984	1985	1986	1987	1988
Denmark	-	-	-	-	-	-	446	3,283	2,793
France	3,361	3,711	3.073	2,643	2,489	4,305	3,534	3,983	4,502
Netherlands	-	-	-	-	-[2]	-[2]	-[2]	-[2]	-
Spain	34,134	36,362	19,610	25,580	23,119	23,292	40,334	30,098	26,629
UK (Engl.+Wales)	-	+	1	-	1	143	392	339	253
USSR	-	-	-	-	20	-	656	-	-
Total	37,495	40,073	22,684	28,223	25,629	27,740	45,362	37,703	34,177

Country	1989	1990	1991	1992	1993	1994	1995	1996	1997
Denmark	6,729	5,726	1,349	5,778	1,955	-	340	140	729
France	4,719	5,082	6,164	6,220	4,010	28	-	7	8,690
Germany, Fed. Rep.	-	-	80	62	-		-	-	-
Netherlands	-	6,000	12,437	9,339	19,000	7,272	-	14,187	2,944
Spain	27,170	25,182	23,733	27,688	27,921	25,409	28,349	29,428	31,081
UK (Engl.+Wales)	68	6	70	88	123	753	20	924	430
USSR/Russia (1992-)	-	-	-	-	-	-	-	-	-
Unallocated+discards	-	1,500	2,563	5,011	700	2,038	-	3,583	-2,944
Total	38,686	43,496	46,396	54,186	53,709	35,500	28,709	48,269	40,930

Country	1998	1999	2000	2001	2002	2003	2004	2005	2006
Denmark	1,728	4,818	2,584	582	-	-		-	1,513
France	1,844	74	7	5,316	13,676	-	2,161	3,540	3,944
Germany	3,268	3,197	3,760	3,645	2,249	4,908	72	4,776	3,325
Ireland	-	-	6,485	1,483	704	504	1,882	1,808	158
Lithuania									401
Netherlands	6,604	22,479	11,768	36,106	12,538	1,314	1,047	6,607	6,073
Russia	-	-	-	-	-	6,620			-
Spain	23,599	24,190	24,154	23,531	22,110	24,598	16,245	16,624	13,874
UK (Engl. + Wales)	9	29	112	1,092	157	982	516	838	821
UK (Scotland)	-	-	249	-	-	-		-	-
Unallocated+discards	1,884	-8658	5,093	4,365	1,705	2,785	2,202	7,302	4,013
Total	38,936	46,129	54,212	76,120	54,560	41,711	24,125	41,495	34,122

Country	2007	2008	2009	2010	2011	2012[1]
Denmark	2,687	3,289	3,109	632	200	581
France	10,741	2,848	-	-	326[3]	1216
Germany	-	918	281	64	61	-
Ireland	694	246	-	-	-	39
Lithuania	-	-	-	-	-	-
Netherland	-	6,269	1,849	97	49	
Russia	-	-	-	-	-	7
Spain	13,853	19,840	21,071	38,740	34,581	-
UK (Engl. + Wales)	-	-	-	-	28	13,502
UK (Scotland)	-	-	-	-	-	-
Unallocated+discards	412	482	7,045	3,694		2057
Total	28,387	33,892	33,355	43,227	35,245	17,402

[1]Preliminary.

[2]Included in Subarea VII.

[3]French catches landed in the Netherlands

Table 5.2.2.1. Western horse mackerel. The time series of egg production estimates (10^{-12} eggs).

Year	Total egg production
1983	513
1989	1762
1992	1712
1995	1265
1998	1136
2001	821
2004	889
2007	1640
2010	1093
2013	395

Table 5.2.4.1. Western Horse Mackerel stock. Catch in numbers (1000) at age by quarter and area in 2012

1Q Ages	IIa	IIIa	IVa	Vb	VIa	VIIa	VIIb	VIIc	VIIe	VIIf	VIIg	VIIh	VIIj	VIIk	VIIIa	VIIIb	VIIIc	VIIIc	Total
0					0		0	0	0	0	0	0	0	0	0	0	0	0	0
1					0		0	0	2855	0	0	0	0	0	7440	4283	687	5264	20530
2					0		0	0	5183	0	0	270	0	0	1335	396	375	5234	12793
3					338		0	0	8522	0	0	865	1975	0	2157	51	447	3362	17718
4					9760		462	0	8701	0	0	1454	3457	0	3529	29	530	689	28612
5					2362		1297	0	2285	0	0	109	829	0	283	13	560	227	7966
6					1347		3682	287	1647	0	0	0	1146	0	5	3	369	31	8516
7					1427		4772	573	785	0	0	0	2470	61	6	4	352	11	10463
8					1915		3659	287	592	0	0	0	1682	246	1	0	269	14	8665
9					3856		7206	430	134	0	0	0	3594	123	1	0	184	12	15540
10					1164		12789	1364	0	0	0	0	3638	369	1	0	366	80	19769
11					25212		29746	2839	0	0	0	0	19465	491	2	1	232	112	78101
12					3018		22837	1438	0	0	0	0	4162	184	1	1	321	107	32069
13					2242		3905	1040	0	0	0	0	2829	61	1	1	191	78	10348
14					1959		1588	616	0	0	0	0	1223	0	3	2	176	106	5672
15+					2374		7533	1740	0	0	0	0	6772	0	8	5	296	423	19153
Sum	0	0	0	0	56974	0	99478	10612	30704	1	0	2698	53241	1536	14774	4789	5355	15750	295913

2Q Ages	IIa	IIIa	IVa	Vb	VIa	VIIa	VIIb	VIIc	VIIe	VIIf	VIIg	VIIh	VIIj	VIIk	VIIIa	VIIIb	VIIIc east	VIIIc	Total
0					0		0	0	0	0		0	0	0	0	0	0	0	0
1					0		0	0	44	0		0	0	0	427	7760	1641	4446	14318
2					0		0	0	80	0		0	0	0	88	1604	1109	4185	7067
3					0		0	0	143	0		0	0	0	26	478	632	3159	4439
4					0		22	0	147	0		0	686	7	22	403	253	920	2460
5					2		177	777	47	0		0	4672	46	34	610	403	627	7396
6					0		269	0	29	0		0	8184	81	33	604	510	468	10178
7					0		177	0	13	0		0	5383	53	53	965	843	650	8137
8					6		172	2330	9	0		0	3044	30	47	860	917	364	7781
9					2		475	777	2	0		1	13755	136	38	682	708	325	16899
10					2		293	777	0	0		0	8183	81	65	1173	1410	768	12753
11					30		1057	10874	1	0		1	21904	216	36	662	856	503	36140
12					2		316	777	0	0		0	8888	88	48	863	1239	507	12727
13					4		240	1553	0	0		0	5853	58	27	495	715	251	9197
14					0		77	0	0	0		0	2340	23	21	386	693	254	3794
15+					4		102	1553	1	0		0	1638	16	29	526	1402	440	5712
Sum	0	0	0	0	53	0	3377	19418	517	0	0	4	84531	833	995	18071	13332	17867	158999

Table 5.2.4.1 cont. Western Horse Mackerel stock. Catch in numbers (1000) at age by quarter and area in 2012

3Q Ages	IIa	IIIa	IVa	Vb	VIa	VIIa	VIIb	VIIc	VIIe	VIIf	VIIg	VIIh	VIIj	VIIk	VIIIa	VIIIb	VIIIc	VIIIc	Total
0	0	0	0	0			0	0	0	0	0	0	0	0	174	960	202	1443	2780
1	0	0	0	0			0	0	0	0	0	0	0	0	1	6	3	544	553
2	0	0	0	0			0	0	12	0	0	3	0	0	7	28	2	1522	1575
3	9	0	2	532			265	269	835	0	1	174	0	0	177	228	44	354	2893
4	54	0	19	3116			1555	1579	919	0	1	192	194	0	292	789	185	127	9023
5	42	1	22	2437			1216	1235	842	0	1	175	1320	0	241	575	183	111	8403
6	12	0	8	709			354	359	286	0	0	60	2312	0	160	626	310	70	5266
7	2	0	5	118			59	60	48	0	0	10	1521	0	52	242	268	18	2403
8	2	0	7	118			59	60	0	0	0	0	860	0	60	333	764	18	2282
9	2	1	18	118			59	60	0	0	0	0	3886	0	26	143	675	9	4997
10	2	1	23	118			59	60	0	0	0	0	2312	0	27	151	1139	50	3943
11	24	4	63	1374			685	696	40	0	0	8	6188	0	14	39	548	63	9745
12	4	1	17	222			111	112	0	0	0	0	2511	0	2	11	430	98	3518
13	0	0	5	0			0	0	0	0	0	0	1654	0	3	19	275	69	2026
14	0	0	4	0			0	0	0	0	0	0	661	0	5	29	431	147	1279
15+	0	0	2	0			0	0	40	0	0	8	463	0	24	96	880	497	2010
Sum	152	10	195	8862	0	0	4422	4490	3022	1	5	630	23881	0	1266	4276	6340	5142	62694

4Q Ages	IIa	IIIa	IVa	Vb	VIa	VIIa	VIIb	VIIc	VIIe	VIIf	VIIg	VIIh	VIIj	VIIk	VIIIa	VIIIb	VIIIc	VIIIc	Total
0	0	0	0		0		0	0	0	0	0	0	0	0	85	609	81	1795	2570
1	0	0	0		0		0	0	3337	0	33	6318	1320	0	165	16	9	1498	12695
2	0	0	0		0		52	1	8644	1	83	8925	1866	0	371	74	9	1193	21219
3	0	0	0		9807		156	841	16234	1	159	8925	1870	0	628	116	131	303	39171
4	4	1	358		80755		11332	7130	18894	1	182	9224	2322	0	706	24	124	132	131190
5	8	1	732		7452		5258	755	11384	1	113	4813	1188	0	417	3	45	78	32247
6	3	0	288		2787		2072	285	7250	1	72	652	208	0	246	1	39	54	13957
7	3	1	299		2221		2285	241	1867	0	15	0	80	0	62	1	25	29	7129
8	4	1	379		3971		1217	370	735	0	7	0	42	0	24	0	63	65	6880
9	11	2	1054		3396		2288	354	740	0	7	0	80	0	25	1	53	43	8054
10	15	2	1381		2419		233	235	213	0	2	0	8	0	7	0	99	175	4790
11	38	6	3483		23194		8443	2211	230	0	2	0	294	0	8	0	50	173	38132
12	11	2	1013		805		0	86	0	0	0	0	0	0	0	0	54	239	2209
13	3	1	297		1391		410	132	24	0	0	0	14	0	1	0	41	158	2472
14	3	0	255		236		0	25	0	0	0	0	0	0	0	0	68	289	876
15+	1	0	131		2117		104	185	0	0	0	0	4	0	0	0	159	990	3692
Sum	104	17	9671	0	140552	0	33851	12852	69553	5	675	38856	9296	0	2744	846	1049	7212	327282

Table 5.2.4.1 cont. Western Horse Mackerel stock. Catch in numbers (1000) at age by quarter and area in 2012

1-4Q																			
Ages	IIa	IIIa	IVa	Vb	VIa	VIIa	VIIb	VIIc	VIIe	VIIf	VIIg	VIIh	VIIj	VIIk	VIIIa	VIIIb	VIIIc east	VIIIc west	Total
0	0	0	0		0		0	0	0	0	0	0	0	0	259	1569	283	3238	5349
1	0	0	0		0		0	0	6236	0	33	6318	1320	0	8034	12064	2340	11751	48096
2	0	0	0		0		52	1	13920	1	83	9198	1866	0	1801	2103	1495	12133	42653
3	9	0	2		10676		422	1110	25735	2	161	9963	3845	0	2989	874	1255	7179	64222
4	57	1	377		93632		13372	8709	28661	2	183	10870	6658	7	4549	1245	1092	1868	171284
5	50	2	754		12254		7949	2766	14557	1	114	5097	8010	46	975	1201	1191	1043	56011
6	15	1	295		4843		6376	930	9212	1	72	712	11851	81	443	1233	1228	623	37916
7	5	1	304		3767		7292	874	2713	0	15	10	9453	114	173	1211	1488	709	28132
8	6	1	386		6011		5108	3047	1336	0	7	0	5629	276	133	1194	2014	461	25608
9	13	3	1072		7372		10029	1621	877	0	7	1	21314	258	89	826	1619	390	45490
10	17	4	1404		3703		13373	2436	213	0	2	0	14141	449	100	1325	3014	1072	41255
11	61	10	3546		49809		39932	16620	271	0	2	9	47851	707	59	703	1687	851	162118
12	15	3	1030		4047		23264	2413	0	0	0	0	15561	272	51	874	2044	950	50523
13	3	1	302		3637		4556	2726	24	0	0	0	10350	119	33	515	1222	556	24043
14	3	1	260		2195		1665	640	0	0	0	0	4224	23	30	417	1368	796	11621
15+	1	0	133		4495		7740	3479	40	0	0	8	8876	16	61	628	2738	2350	30567
Sum	256	27	9866	0	206442	0	141129	47372	103796	8	679	42188	170949	2369	19779	27982	26075	45971	844888

Table 5.2.4.2. Western horse mackerel. Catch-at-age (thousands of fish).

	0	1	2	3	4	5	6	7	8	9	10	11+
1982	0	3713	21072	134743	11515	13197	11741	8848	1651	414	1651	81385
1983	0	7903	2269	32900	53508	15345	44539	52673	17923	3291	5505	129139
1984	0	0	241360	4439	36294	149798	22350	38244	34020	14756	4101	58370
1985	0	1633	4901	602992	4463	41822	100376	12644	16172	6200	9224	40976
1986	0	0	0	1548	676208	8727	65147	109747	25712	21179	15271	56824
1987	0	99	493	0	2950	891660	2061	41564	90814	11740	9549	62776
1988	876	27369	6112	2099	4402	18968	941725	12115	39913	67869	9739	76096
1989	0	0	0	20766	18282	5308	14500	1276731	12046	59357	83125	78951
1990	0	20406	45036	138929	61442	33298	10549	20607	1384850	37011	70512	226294
1991	20632	33560	89715	23034	207751	143072	73730	25369	25584	1219646	23987	137131
1992	14887	229703	36331	80552	56275	256085	127048	49020	19053	23449	1103480	152305
1993	46	109152	94500	16738	62714	94711	317337	144610	70717	32693	4822	1309609
1994	3686	60759	911713	115729	53132	44692	38769	221970	106512	40799	42302	998180
1995	2702	165382	470498	424563	215468	59035	90832	35654	245230	119117	99495	1362342
1996	10729	19774	658727	860992	186306	85508	51365	55229	53379	57131	56962	729283
1997	4860	110145	465350	735919	410638	244328	119062	127658	134488	109962	109165	601196
1998	744	91505	184443	488662	360116	219650	157396	122583	81499	68264	50555	389594
1999	14822	97561	83714	176919	265820	254516	212225	187250	147328	77691	35635	252044
2000	637	78856	131112	52716	71779	150869	170393	177995	133290	61578	18010	168770
2001	58685	69430	246525	151707	98454	101344	116952	234832	203823	103968	36076	132706
2002	13707	461055	120106	164977	126329	64449	69828	94429	130285	85325	45798	150103
2003	1843	303721	585700	165666	152117	88944	57445	45596	49476	92758	50503	109994
2004	21246	140299	110976	474273	76136	103011	69844	43981	31618	49188	56109	63823
2005	1260	71508	170936	310085	531221	68559	74392	61641	43454	22304	27127	99898
2006	1901	49396	39439	41585	73860	501168	57299	39424	43667	17148	12274	102329
2007	4583	37208	39743	46218	63337	105042	336626	48066	27637	20155	8801	59268
2008	29912	76358	19219	41715	46963	74125	47740	294659	50621	36873	25725	73986
2009	46167	117519	46258	39576	33781	38393	55696	53917	248299	66292	41751	107948
2010	6806	82287	159023	93764	32789	31381	52379	104625	72210	269930	68571	129653
2011	1094	18864	59027	93167	46347	41372	35607	60798	63676	78422	246442	177090
2012	5350	48100	42654	64222	171285	56012	37917	28132	25608	45490	41255	278872

Table 5.2.5.1. Western horse mackerel stock. Mean weight (kg) in catch at age by quarter and area in 2012.

1Q Ages	IIa	IIIa	IVa	Vb	VIa	VIIa	VIIb	VIIc	VIIe	VIIf	VIIg	VIIh	VIIj	VIIk	VIIIa	VIIIb	VIIIc east	VIIIc	Mean
1									0.054	0.054	0.054				0.047	0.047	0.056	0.075	0.06
2									0.064	0.065	0.065	0.073			0.068	0.063	0.082	0.082	0.07
3					0.093				0.087	0.086	0.085	0.085	0.077		0.085	0.092	0.105	0.094	0.09
4					0.125		0.140		0.106	0.105	0.101	0.099	0.088		0.099	0.127	0.133	0.108	0.11
5					0.156		0.181		0.133	0.133	0.130	0.126	0.122		0.127	0.149	0.160	0.131	0.14
6					0.201		0.189	0.207	0.151	0.151	0.162		0.181		0.167	0.167	0.179	0.162	0.17
7					0.229		0.223	0.196	0.179	0.179	0.196		0.202	0.209	0.202	0.202	0.198	0.198	0.20
8					0.244		0.227	0.218	0.154	0.154	0.198		0.217	0.202	0.183	0.183	0.225	0.210	0.20
9					0.249		0.235	0.214	0.198	0.198	0.213		0.214	0.195	0.369	0.369	0.248	0.258	0.25
10					0.275		0.294	0.236			0.241		0.241	0.207	0.259	0.259	0.265	0.338	0.26
11					0.293		0.263	0.239			0.250		0.250	0.216	0.350	0.350	0.282	0.376	0.29
12					0.327		0.303	0.246			0.291		0.291	0.237	0.343	0.343	0.290	0.377	0.30
13					0.372		0.277	0.255			0.323		0.323	0.200	0.315	0.315	0.286	0.402	0.31
14					0.378		0.309	0.262			0.342		0.342		0.421	0.421	0.321	0.423	0.36
15+					0.410		0.434	0.272			0.344		0.344		0.420	0.420	0.363	0.512	0.39
Mean					0.26		0.26	0.23	0.13	0.12	0.20	0.10	0.22	0.21	0.23	0.23	0.21	0.25	

2Q Ages	IIa	IIIa	IVa	Vb	VIa	VIIa	VIIb	VIIc	VIIe	VIIf	VIIg	VIIh	VIIj	VIIk	VIIIa	VIIIb	VIIIc east	VIIIc west	Mean
1									0.054						0.049	0.049	0.064	0.072	0.06
2									0.064						0.069	0.069	0.079	0.083	0.07
3									0.089						0.093	0.093	0.094	0.097	0.09
4							0.119		0.108	0.119		0.119	0.119	0.119	0.133	0.133	0.124	0.117	0.12
5					0.153		0.142	0.153	0.136	0.141		0.141	0.141	0.141	0.172	0.172	0.166	0.151	0.15
6							0.163		0.152	0.163		0.163	0.163	0.163	0.189	0.189	0.185	0.182	0.17
7							0.177		0.178	0.177		0.177	0.177	0.177	0.206	0.206	0.201	0.200	0.19
8					0.202		0.202	0.202	0.154	0.203		0.203	0.203	0.203	0.229	0.229	0.229	0.222	0.21
9					0.217		0.241	0.217	0.198	0.242		0.242	0.242	0.242	0.247	0.247	0.252	0.240	0.24
10					0.198		0.226	0.198		0.228		0.228	0.228	0.228	0.260	0.260	0.266	0.284	0.24
11					0.230		0.245	0.230	0.310	0.252		0.252	0.252	0.252	0.272	0.272	0.287	0.310	0.26
12					0.240		0.270	0.240		0.273		0.273	0.273	0.273	0.274	0.274	0.295	0.309	0.27
13					0.261		0.277	0.261		0.281		0.281	0.281	0.281	0.268	0.268	0.296	0.303	0.28
14							0.311			0.311		0.311	0.311	0.311	0.291	0.291	0.330	0.334	0.31
15+					0.284		0.317	0.284	0.232	0.346		0.346	0.346	0.346	0.296	0.296	0.392	0.405	0.32
Mean					0.22		0.22	0.22	0.15	0.23		0.23	0.23	0.23	0.20	0.20	0.22	0.22	

Table 5.2.5.1 cont. Western horse mackerel stock. Mean weight (kg) in catch at age by quarter and area in 2012.

3Q Ages	IIa	IIIa	IVa	Vb	VIa	VIIa	VIIb	VIIc	VIIe	VIIf	VIIg	VIIh	VIIj	VIIk	VIIIa	VIIIb	VIIIc east	VIIIc west	Mean
															0.047	0.047	0.035	0.059	0.05
1															0.085	0.085	0.073	0.084	0.08
2									0.096	0.096	0.096	0.096			0.080	0.074	0.094	0.105	0.09
3	0.150		0.150		0.150		0.150	0.150	0.119	0.119	0.119	0.119			0.131	0.172	0.122	0.128	0.14
4	0.172	0.239	0.193		0.172		0.172	0.172	0.131	0.131	0.131	0.131	0.119		0.162	0.194	0.159	0.138	0.16
5	0.206	0.255	0.232		0.206		0.206	0.206	0.145	0.145	0.145	0.145	0.141		0.175	0.215	0.181	0.153	0.18
6	0.213	0.280	0.254		0.213		0.213	0.213	0.157	0.157	0.157	0.157	0.163		0.212	0.235	0.202	0.186	0.20
7	0.277	0.277	0.277		0.277		0.277	0.277	0.157	0.157	0.157	0.157	0.177	0.209	0.230	0.243	0.231	0.197	0.22
8	0.277	0.302	0.300		0.277		0.277	0.277					0.203	0.202	0.267	0.267	0.240	0.228	0.26
9	0.277	0.333	0.331		0.277		0.277	0.277					0.242	0.195	0.292	0.292	0.256	0.258	0.28
10	0.277	0.329	0.328		0.277		0.277	0.277					0.228	0.207	0.293	0.293	0.283	0.322	0.28
11	0.254	0.342	0.334		0.254		0.254	0.254	0.310	0.310	0.310	0.310	0.252	0.216	0.309	0.307	0.303	0.375	0.29
12	0.254	0.405	0.397		0.254		0.254	0.254					0.273	0.237	0.329	0.329	0.324	0.405	0.31
13		0.415	0.415										0.281	0.200	0.291	0.291	0.340	0.403	0.33
14		0.422	0.422										0.311		0.293	0.293	0.328	0.460	0.36
15+		0.478	0.478						0.232	0.232	0.232	0.232	0.346		0.268	0.281	0.314	0.517	0.33
Mean	0.24	0.34	0.32		0.24		0.24	0.24	0.17	0.17	0.17	0.17	0.23	0.21	0.22	0.23	0.22	0.25	

4Q Ages	IIa	IIIa	IVa	Vb	VIa	VIIa	VIIb	VIIc	VIIe	VIIf	VIIg	VIIh	VIIj	VIIk	VIIIa	VIIIb	VIIIc east	VIIIc west	Mean
															0.059	0.059	0.037	0.066	0.06
1									0.074	0.074	0.074	0.072	0.072		0.073	0.091	0.078	0.084	0.08
2							0.104	0.104	0.091	0.091	0.091	0.088	0.088	0.104	0.090	0.084	0.093	0.102	0.09
3					0.130		0.113	0.130	0.114	0.113	0.113	0.106	0.106	0.113	0.113	0.116	0.115	0.130	0.12
4	0.239	0.239	0.239		0.164		0.171	0.164	0.130	0.130	0.130	0.123	0.131	0.171	0.129	0.136	0.147	0.142	0.16
5	0.255	0.255	0.255		0.204		0.201	0.204	0.145	0.145	0.145	0.135	0.145	0.201	0.144	0.201	0.171	0.149	0.18
6	0.280	0.280	0.280		0.233		0.233	0.234	0.159	0.159	0.159	0.161	0.186	0.233	0.159	0.223	0.197	0.194	0.21
7	0.277	0.277	0.277		0.239		0.233	0.239	0.186	0.186	0.185		0.233	0.233	0.186	0.187	0.228	0.212	0.23
8	0.302	0.302	0.302		0.262		0.245	0.262	0.198	0.198	0.193		0.245	0.245	0.198	0.292	0.240	0.230	0.25
9	0.333	0.333	0.333		0.257		0.236	0.258	0.223	0.223	0.227		0.236	0.236	0.223	0.292	0.259	0.257	0.26
10	0.329	0.329	0.329		0.309		0.266	0.310	0.206	0.206	0.206		0.266	0.266	0.207	0.304	0.286	0.313	0.28
11	0.342	0.342	0.342		0.299		0.253	0.297	0.240	0.240	0.242		0.253	0.253	0.241	0.327	0.310	0.365	0.29
12	0.405	0.405	0.405		0.371			0.378							0.412	0.412	0.349	0.394	0.39
13	0.415	0.415	0.415		0.327		0.243	0.325	0.182	0.182	0.182		0.243	0.243	0.186	0.455	0.369	0.398	0.31
14	0.422	0.422	0.422		0.408			0.411							0.435	0.435	0.384	0.439	0.42
15+	0.478	0.478	0.478		0.329		0.316	0.331					0.316	0.316	0.327	0.327	0.414	0.498	0.38
Mean	0.34	0.34	0.34		0.27		0.22	0.26	0.16	0.16	0.16	0.11	0.19	0.22	0.20	0.25	0.23	0.25	

Table 5.2.5.1 cont. Western horse mackerel stock. Mean weight (kg) in catch at age by quarter and area in 2012.

1-4Q Ages	IIa	IIIa	IVa	Vb	VIa	VIIa	VIIb	VIIc	VIIe	VIIf	VIIg	VIIh	VIIj	VIIk	VIIIa	VIIIb	VIIIc east	VIIIc west	Mean
															0.051	0.051	0.036	0.063	0.05
1									0.065	0.067	0.074	0.072	0.072		0.047	0.048	0.062	0.075	0.06
2							0.104	0.104	0.081	0.084	0.091	0.088	0.088	0.104	0.073	0.069	0.080	0.087	0.09
3	0.150		0.150		0.130		0.136	0.135	0.105	0.109	0.113	0.104	0.091	0.113	0.094	0.117	0.101	0.099	0.12
4	0.177	0.239	0.237		0.160		0.170	0.166	0.123	0.125	0.130	0.120	0.107	0.119	0.108	0.171	0.137	0.117	0.15
5	0.214	0.255	0.255		0.195		0.197	0.191	0.143	0.144	0.145	0.135	0.139	0.141	0.148	0.192	0.166	0.146	0.18
6	0.227	0.280	0.279		0.221		0.203	0.217	0.158	0.159	0.159	0.161	0.165	0.163	0.181	0.212	0.188	0.182	0.20
7	0.277	0.277	0.277		0.236		0.225	0.213	0.184	0.181	0.185	0.158	0.184	0.194	0.206	0.214	0.206	0.200	0.21
8	0.294	0.302	0.302		0.257		0.231	0.212	0.178	0.186	0.193	0.203	0.207	0.202	0.240	0.240	0.233	0.223	0.23
9	0.324	0.333	0.333		0.253		0.235	0.227	0.219	0.231	0.227	0.242	0.237	0.219	0.255	0.255	0.254	0.243	0.26
10	0.323	0.329	0.329		0.297		0.292	0.232	0.206	0.221	0.206	0.228	0.232	0.211	0.265	0.264	0.273	0.294	0.26
11	0.308	0.342	0.342		0.295		0.260	0.241	0.251	0.258	0.244	0.303	0.251	0.227	0.278	0.274	0.292	0.334	0.28
12	0.366	0.405	0.405		0.332		0.302	0.249		0.273	0.291	0.273	0.278	0.248	0.278	0.275	0.302	0.348	0.31
13	0.415	0.415	0.415		0.355		0.274	0.262	0.182	0.274	0.248	0.281	0.292	0.239	0.270	0.269	0.307	0.356	0.30
14	0.422	0.422	0.422		0.382		0.310	0.268		0.311	0.342	0.311	0.320	0.311	0.305	0.292	0.331	0.407	0.34
15+	0.478	0.478	0.478		0.372		0.431	0.280	0.232	0.266	0.235	0.233	0.345	0.346	0.302	0.294	0.365	0.487	0.35
Mean	0.31	0.34	0.32		0.27		0.24	0.21	0.16	0.19	0.19	0.19	0.20	0.20	0.19	0.20	0.21	0.23	

Table 5.2.5.2. Western horse mackerel stock. Mean length (cm) in catch at age by quarter and area in 2012.

1Q Ages	IIa	IIIa	IVa	Vb	VIa	VIIa	VIIb	VIIc	VIIe	VIIf	VIIg	VIIh	VIIj	VIIk	VIIIa	VIIIb	VIIIc east	VIIIc west	Mean
1									19.21	19.21	19.21				17.56	17.56	18.59	20.77	18.87
2									20.29	20.36	20.36	21.50			20.51	19.58	21.44	21.40	20.68
3					23.23				22.39	22.42	22.36	22.69	22.00		22.68	22.35	23.40	22.52	22.60
4					25.51		26.14		23.86	23.89	23.85	24.05	23.71		24.07	24.94	25.39	23.57	24.45
5					27.36		28.41		25.56	25.58	25.74	26.00	26.27		26.04	26.47	27.13	25.24	26.35
6					29.63		29.14	29.50	26.45	26.45	27.35		28.92		27.51	27.51	28.25	27.23	27.99
7					30.90		30.13	29.25	27.23	27.23	29.12		29.85	29.50	29.45	29.45	29.23	29.25	29.22
8					31.50		30.59	31.00	26.90	26.90	29.76		30.99	29.50	28.39	28.39	30.60	29.77	29.52
9					31.74		31.30	29.83	28.50	28.50	30.67		30.77	29.00	36.16	36.16	31.59	32.01	31.35
10					32.71		32.93	31.29			31.82		31.82	30.50	31.88	31.88	32.38	35.21	32.24
11					33.35		32.22	31.46			32.24		32.24	30.75	35.42	35.42	33.03	36.55	33.27
12					34.28		33.38	31.96			33.91		33.91	31.50	35.27	35.27	33.31	36.56	33.94
13					35.73		32.35	32.17			34.69		34.69	29.50	34.05	34.05	33.12	37.43	33.78
14					36.03		33.48	33.04			34.90		34.90		37.90	37.90	34.45	38.07	35.63
15+					37.22		36.31	32.86			35.15		35.15		37.98	37.98	35.79	40.65	36.57
Mean					31.48		31.37	31.24	24.49	24.50	28.74	23.56	30.40	30.04	29.66	29.66	29.18	30.42	

2Q Ages	IIa	IIIa	IVa	Vb	VIa	VIIa	VIIb	VIIc	VIIe	VIIf	VIIg	VIIh	VIIj	VIIk	VIIIa	VIIIb	VIIIc east	VIIIc west	Mean
1									19.21						17.81	17.81	19.48	20.42	18.95
2									20.30						20.16	20.16	21.14	21.49	20.65
3									22.51						22.41	22.41	22.47	22.75	22.51
4							25.00		23.93	25.00		25.00	25.00	25.00	25.37	25.37	24.76	24.22	24.87
5					28.50		26.47	28.50	25.54	26.15		26.15	26.15	26.15	27.77	27.77	27.48	26.49	26.93
6							27.68		26.40	27.68		27.68	27.68	27.68	28.73	28.73	28.55	28.38	27.92
7							28.43		27.20	28.43		28.43	28.43	28.43	29.65	29.65	29.42	29.34	28.74
8					30.17		29.74	30.17	26.90	29.43		29.43	29.43	29.43	30.79	30.79	30.76	30.43	29.79
9					30.50		31.20	30.50	28.50	31.23		31.23	31.23	31.23	31.58	31.58	31.76	31.28	30.99
10					29.50		30.54	29.50		30.63		30.63	30.63	30.63	32.15	32.15	32.39	33.10	31.08
11					31.64		31.92	31.64	34.50	32.05		32.05	32.05	32.05	32.63	32.63	33.22	34.08	32.54
12					31.50		32.76	31.50		32.86		32.86	32.86	32.86	32.72	32.72	33.51	34.08	32.75
13					33.00		33.15	33.00		33.19		33.19	33.19	33.19	32.45	32.45	33.52	33.70	33.09
14							34.43			34.43		34.43	34.43	34.43	33.36	33.36	34.79	34.93	34.29
15+					34.50		35.05	34.50	29.50	35.54		35.54	35.54	35.54	33.50	33.50	36.73	37.14	34.72
Mean					31.16		30.53	31.16	25.86	30.55		30.55	30.55	30.55	28.74	28.74	29.33	29.46	

Table 5.2.5.2 cont. Western horse mackerel stock. Mean length (cm) in catch at age by quarter and area in 2012.

3Q Ages	IIa	IIIa	IVa	Vb	VIa	VIIa	VIIb	VIIc	VIIe	VIIf	VIIg	VIIh	VIIj	VIIk	VIIIa	VIIIb	VIIIc east	VIIIc west	Mean
															17.50	17.50	15.65	19.00	17.41
1															21.73	21.73	20.53	21.68	21.42
2									21.83	21.83	21.83	21.83			21.03	20.71	22.51	23.39	21.87
3	25.94		25.94		25.94		25.94	25.94	23.84	23.84	23.84	23.84			24.75	27.74	24.64	25.13	25.18
4	27.24	28.80	27.72		27.24		27.24	27.24	24.63	24.63	24.63	24.63	25.00		26.77	29.01	27.05	25.76	26.51
5	29.09	29.90	29.53		29.09		29.09	29.09	25.45	25.45	25.45	25.45	26.15		27.46	30.09	28.35	26.60	27.75
6	29.46	30.60	30.16		29.46		29.46	29.46	26.09	26.09	26.09	26.09	27.68		29.62	31.07	29.41	28.65	28.63
7	32.50	30.20	30.41		32.50		32.50	32.50	26.76	26.76	26.76	26.76	28.43	29.50	30.70	31.40	30.81	29.19	29.86
8	32.50	30.80	30.93		32.50		32.50	32.50					29.43	29.50	32.49	32.49	31.26	30.72	31.47
9	32.50	32.40	32.40		32.50		32.50	32.50					31.23	29.00	33.52	33.52	32.01	32.09	32.18
10	32.50	32.30	32.30		32.50		32.50	32.50					30.63	30.50	33.52	33.52	33.10	34.60	32.54
11	31.48	32.80	32.68		31.48		31.48	31.48	34.50	34.50	34.50	34.50	32.05	30.75	34.29	34.10	33.89	36.51	33.19
12	31.50	35.00	34.81		31.50		31.50	31.50					32.86	31.50	34.95	34.95	34.73	37.51	33.53
13		34.80	34.80										33.19	29.50	33.44	33.44	35.20	37.50	33.98
14		35.10	35.10										34.43		33.53	33.53	34.80	39.19	35.10
15+		36.60	36.60						29.50	29.50	29.50	29.50	35.54		32.06	33.01	34.22	40.73	33.34
Mean	30.47	32.44	31.80		30.47		30.47	30.47	26.58	26.58	26.58	26.58	30.55	30.04	29.21	29.86	29.26	30.52	

4Q Ages	IIa	IIIa	IVa	Vb	VIa	VIIa	VIIb	VIIc	VIIe	VIIf	VIIg	VIIh	VIIj	VIIk	VIIIa	VIIIb	VIIIc east	VIIIc west	Mean
															19.02	19.02	15.86	19.91	18.45
1									20.23	20.22	20.22	19.93	19.93		20.16	22.29	21.12	21.63	20.64
2							23.50	23.50	21.84	21.83	21.81	21.40	21.40	23.50	21.74	21.56	22.44	23.16	22.31
3					25.09		24.17	25.09	23.81	23.80	23.80	22.89	22.90	24.17	23.71	24.11	24.13	25.24	24.07
4	28.80	28.80	28.80		27.10		27.84	27.13	24.83	24.83	24.84	24.64	25.19	27.84	24.81	25.36	26.32	26.02	26.45
5	29.90	29.90	29.90		29.15		29.49	29.21	25.71	25.71	25.69	25.58	26.19	29.49	25.70	29.39	27.75	26.37	27.82
6	30.60	30.60	30.60		30.52		31.00	30.59	26.48	26.48	26.45	27.50	28.71	31.00	26.51	30.50	29.20	29.04	29.11
7	30.20	30.20	30.20		30.78		31.05	30.82	27.48	27.48	27.43		31.05	31.05	27.48	28.54	30.65	29.94	29.62
8	30.80	30.80	30.80		31.71		31.58	31.69	28.09	28.09	27.87		31.58	31.58	28.11	33.54	31.27	30.81	30.55
9	32.40	32.40	32.40		31.45		31.19	31.47	28.69	28.69	28.81		31.19	31.19	28.71	33.52	32.11	32.03	31.08
10	32.30	32.30	32.30		33.30		32.50	33.18	27.50	27.50	27.50		32.50	32.50	27.55	33.97	33.23	34.27	31.49
11	32.80	32.80	32.80		33.04		31.92	32.95	29.11	29.11	29.19		31.92	31.92	29.13	34.76	34.17	36.16	32.12
12	35.00	35.00	35.00		35.44			35.35							37.80	37.80	35.57	37.13	36.01
13	34.80	34.80	34.80		34.03		31.50	33.90	27.50	27.50	27.50		31.50	31.50	27.66	39.15	36.26	37.31	32.65
14	35.10	35.10	35.10		36.65			36.37							38.50	38.50	36.68	38.51	36.72
15+	36.60	36.60	36.60		34.10		34.50	34.14					34.50	34.50	34.65	34.65	37.53	40.18	35.71
Mean	32.44	32.44	32.44		31.72		30.02	31.10	25.94	25.94	25.93	23.66	28.35	30.02	27.58	30.42	29.64	30.48	

Table 5.2.5.2 cont. Western horse mackerel stock. Mean length (cm) in catch at age by quarter and area in 2012.

1-4Q Ages	IIa	IIIa	IVa	Vb	VIa	VIIa	VIIb	VIIc	VIIe	VIIf	VIIg	VIIh	VIIj	VIIk	VIIIa	VIIIb	VIIIc east	VIIIc west	Mean
															17.99	18.09	15.71	19.50	17.82
1									19.76	19.90	20.22	19.93	19.93		17.63	17.73	19.23	20.79	19.46
2							23.50	23.50	21.25	21.44	21.81	21.40	21.40	23.50	20.75	20.11	21.22	21.85	21.81
3	25.94		25.94		25.07		25.28	25.29	23.33	23.52	23.80	22.89	22.44	24.17	23.01	24.02	23.05	22.86	24.04
4	27.34	28.80	28.75		26.94		27.71	27.15	24.52	24.61	24.84	24.56	24.40	25.00	24.36	27.66	25.63	24.21	26.03
5	29.22	29.90	29.89		28.79		29.18	28.96	25.67	25.64	25.69	25.59	26.17	26.15	26.30	28.87	27.46	26.22	27.48
6	29.69	30.60	30.59		30.12		29.70	29.82	26.46	26.47	26.45	27.38	27.82	27.68	27.81	29.92	28.70	28.41	28.60
7	31.09	30.20	30.20		30.88		30.40	29.91	27.39	27.47	27.43	26.80	28.83	29.01	29.18	30.00	29.65	29.36	29.24
8	31.36	30.80	30.80		31.66		30.82	30.48	27.56	27.95	27.87	29.43	29.91	29.49	31.05	31.26	30.94	30.48	30.12
9	32.42	32.40	32.40		31.62		31.28	30.61	28.66	29.92	28.81	31.23	31.15	30.17	31.39	31.92	31.86	31.41	31.08
10	32.32	32.30	32.30		33.09		32.87	30.93	27.50	29.64	27.50	30.63	30.94	30.52	32.20	32.31	32.68	33.52	31.33
11	32.29	32.80	32.80		33.15		32.14	31.78	29.92	31.97	29.35	34.22	32.13	31.15	32.63	32.71	33.44	35.01	32.34
12	34.09	35.00	35.00		34.36		33.37	31.91		32.86	33.91	32.86	33.14	31.94	32.88	32.75	33.79	35.48	33.56
13	34.80	34.80	34.80		35.07		32.32	32.73	27.50	32.80	30.84	33.19	33.60	31.29	32.49	32.49	33.93	35.72	33.02
14	35.10	35.10	35.10		36.09		33.52	33.17		34.43	34.90	34.43	34.57	34.43	33.85	33.39	34.84	37.43	34.69
15+	36.60	36.60	36.60		35.75		36.27	33.66	29.50	31.28	29.64	29.56	35.24	35.54	33.55	33.46	35.87	39.81	34.31
Mean	31.71	32.44	31.94		31.74		30.60	29.99	26.08	27.99	27.54	28.27	28.78	29.29	27.94	28.54	28.63	29.50	

Table 5.2.5.3. Western horse mackerel. Stock weights-at-age (kg).

	0	1	2	3	4	5	6	7	8	9	10	11+
1982	0.000	0.000	0.050	0.080	0.207	0.232	0.269	0.280	0.292	0.305	0.369	0.352
1983	0.000	0.000	0.050	0.080	0.171	0.227	0.257	0.276	0.270	0.243	0.390	0.311
1984	0.000	0.000	0.050	0.077	0.122	0.155	0.201	0.223	0.253	0.246	0.338	0.287
1985	0.000	0.000	0.050	0.081	0.148	0.140	0.193	0.236	0.242	0.289	0.247	0.306
1986	0.000	0.000	0.050	0.080	0.105	0.134	0.169	0.195	0.242	0.292	0.262	0.342
1987	0.000	0.000	0.050	0.080	0.105	0.126	0.150	0.171	0.218	0.254	0.281	0.317
1988	0.000	0.000	0.050	0.080	0.105	0.126	0.141	0.143	0.217	0.274	0.305	0.366
1989	0.000	0.000	0.050	0.080	0.105	0.103	0.131	0.159	0.127	0.210	0.252	0.336
1990	0.000	0.000	0.050	0.080	0.105	0.127	0.135	0.124	0.154	0.174	0.282	0.345
1991	0.000	0.000	0.050	0.080	0.121	0.137	0.143	0.144	0.150	0.182	0.189	0.333
1992	0.000	0.000	0.050	0.080	0.105	0.133	0.151	0.150	0.158	0.160	0.182	0.287
1993	0.000	0.000	0.050	0.080	0.105	0.153	0.166	0.173	0.172	0.170	0.206	0.222
1994	0.000	0.000	0.050	0.080	0.105	0.147	0.185	0.169	0.191	0.191	0.190	0.235
1995	0.000	0.000	0.050	0.066	0.119	0.096	0.152	0.166	0.178	0.187	0.197	0.233
1996	0.000	0.000	0.050	0.095	0.118	0.129	0.148	0.172	0.183	0.185	0.202	0.238
1997	0.000	0.000	0.050	0.080	0.112	0.124	0.162	0.169	0.184	0.188	0.208	0.238
1998	0.000	0.000	0.050	0.090	0.108	0.129	0.142	0.151	0.162	0.174	0.191	0.215
1999	0.000	0.000	0.050	0.110	0.120	0.130	0.160	0.170	0.180	0.190	0.210	0.222
2000	0.000	0.000	0.050	0.087	0.108	0.148	0.170	0.173	0.193	0.202	0.257	0.260
2001	0.000	0.000	0.070	0.074	0.082	0.100	0.121	0.131	0.142	0.161	0.187	0.268
2002	0.000	0.000	0.050	0.109	0.120	0.135	0.146	0.153	0.177	0.206	0.216	0.275
2003	0.000	0.000	0.050	0.110	0.142	0.139	0.161	0.169	0.169	0.176	0.176	0.206
2004	0.000	0.000	0.050	0.104	0.114	0.127	0.142	0.157	0.168	0.166	0.178	0.213
2005	0.000	0.000	0.085	0.095	0.110	0.141	0.163	0.182	0.197	0.181	0.209	0.243
2006	0.000	0.000	0.085	0.098	0.095	0.113	0.167	0.157	0.164	0.205	0.195	0.229
2007	0.000	0.000	0.085	0.098	0.095	0.118	0.128	0.137	0.168	0.180	0.173	0.181
2008	0.000	0.000	0.085	0.107	0.128	0.142	0.153	0.160	0.169	0.188	0.263	0.217
2009	0.000	0.000	0.085	0.125	0.15	0.177	0.168	0.169	0.205	0.223	0.217	0.316
2010	0.000	0.050	0.070	0.084	0.114	0.149	0.171	0.182	0.187	0.206	0.221	0.268
2011	0.000	0.070	0.0749	0.086	0.119	0.151	0.171	0.190	0.203	0.220	0.238	0.278
2012	0.000	0.000	0.058[1]	0.077	0.093	0.138	0.165	0.185	0.207	0.236	0.231	0.274

1. Weight at age 2 is the average of the time-series.

Table 5.2.6.1. Western horse mackerel. Maturity-at-age.

	0	1	2	3	4	5	6	7	8	9	10	11+
1982	0	0	0.40	0.80	1	1	1	1	1	1	1	1
1983	0	0	0.30	0.70	1	1	1	1	1	1	1	1
1984	0	0	0.10	0.60	0.85	1	1	1	1	1	1	1
1985	0	0	0.10	0.40	0.80	0.95	1	1	1	1	1	1
1986	0	0	0.10	0.40	0.60	0.90	1	1	1	1	1	1
1987	0	0	0.10	0.40	0.60	0.80	1	1	1	1	1	1
1988	0	0	0.10	0.40	0.60	0.80	1	1	1	1	1	1
1989	0	0	0.10	0.40	0.60	0.80	1	1	1	1	1	1
1990	0	0	0.10	0.40	0.60	0.80	1	1	1	1	1	1
1991	0	0	0.10	0.40	0.60	0.80	1	1	1	1	1	1
1992	0	0	0.10	0.40	0.60	0.80	1	1	1	1	1	1
1993	0	0	0.10	0.40	0.60	0.80	1	1	1	1	1	1
1994	0	0	0.10	0.40	0.60	0.80	1	1	1	1	1	1
1995	0	0	0.10	0.40	0.60	0.80	1	1	1	1	1	1
1996	0	0	0.10	0.40	0.60	0.80	1	1	1	1	1	1
1997	0	0	0.10	0.40	0.60	0.80	1	1	1	1	1	1
1998	0	0	0.05	0.25	0.70	0.95	1	1	1	1	1	1
1999	0	0	0.05	0.25	0.70	0.95	1	1	1	1	1	1
2000	0	0	0.05	0.25	0.70	0.95	1	1	1	1	1	1
2001	0	0	0.05	0.25	0.70	0.95	1	1	1	1	1	1
2002	0	0	0.05	0.25	0.70	0.95	1	1	1	1	1	1
2003	0	0	0.05	0.25	0.70	0.95	1	1	1	1	1	1
2004	0	0	0.05	0.25	0.70	0.95	1	1	1	1	1	1
2005	0	0	0.05	0.25	0.70	0.95	1	1	1	1	1	1
2006	0	0	0.05	0.25	0.70	0.95	1	1	1	1	1	1
2007	0	0	0.05	0.25	0.70	0.95	1	1	1	1	1	1
2008	0	0	0.05	0.25	0.70	0.95	1	1	1	1	1	1
2009	0	0	0.05	0.25	0.70	0.95	1	1	1	1	1	1
2010	0	0	0.05	0.25	0.70	0.95	1	1	1	1	1	1
2011	0	0	0.05	0.25	0.70	0.95	1	1	1	1	1	1
2012	0	0	0.05	0.25	0.7	0.95	1	1	1	1	1	1

Table 5.2.8.1. Western horse mackerel. Potential fecundity (10^6 eggs) per kg spawning female vs. weight in kg.

	1987		1992		1995		1998		2000		2001		2001 (contd)	
	w	pfec.	w	pfec.	w	pfec.	w	pfec.	w	pfec.	w	pfec.	w	pfec.
1	0.168	1.524	0.105	1.317	0.13	1.307	0.172	1.318	0.258	0.841	0.086	0.688	0.165	1.382
2	0.179	0.916	0.109	2.056	0.157	1.246	0.104	0.867	0.268	0.747	0.08	0.812	0.166	1.579
3	0.192	2.083	0.11	1.869	0.168	1.699	0.112	1.312	0.304	1.188	0.081	0.535	0.167	1.479
4	0.233	1.644	0.112	1.772	0.179	1.135	0.206	0.382	0.311	1.411	0.095	0.88	0.113	0.527
5	0.213	1.066	0.115	1.188	0.189	1.529	0.207	0.78	0.337	0.613	0.11	1.164	0.14	0.876
6	0.217	2.392	0.119	1.317	0.168	1.1	0.109	1.133	0.339	1.571	0.113	1.106	0.122	0.589
7	0.277	1.617	0.12	1.413	0.209	1.497	0.132	1.02	0.341	1.522	0.095	0.823	0.12	0.68
8	0.279	1.018	0.123	1.293	0.215	1.524	0.2	1.088	0.355	1.056	0.11	0.883	0.121	0.578
9	0.274	1.62	0.123	1.991	0.218	1.616	0.152	1.417	0.357	0.604	0.108	0.823	0.139	0.723
10	0.3	1.513	0.131	1.617	0.226	1.883	0.149	1.004	0.367	1.15	0.097	0.741	0.144	1.213
11	0.32	1.647	0.135	0.793	0.22	1.324			0.393	1.279	0.101	0.853	0.144	1.265
12	0.273	1.956	0.131	1.039	0.236	1.221			0.393	0.668	0.106	1.133	0.171	0.956
13	0.212	2.83	0.136	1.06	0.261	1.21			0.413	0.694	0.107	0.935	0.121	0.607
14	0.268	1.687	0.138	1.489	0.245	1.445			0.421	1.339	0.107	0.494	0.122	0.689
15	0.32	1.088	0.147	1.214	0.306	1.693			0.423	0.798	0.11	0.85	0.139	0.915
16	0.318	1.208	0.151	1.158	0.314	1.312			0.445	1.03	0.111	0.67	0.153	0.943
17	0.343	1.933	0.16	1.349	0.46	1.575			0.446	1.208	0.103	0.632	0.154	0.709
18	0.378	1.429	0.165	1.359	0.449	1.43			0.152	0.643	0.111	0.547	0.156	0.773
19	0.404	1.849	0.165	0.945					0.165	0.579	0.118	0.88	0.162	1.158
20	0.428	2.236	0.167	1					0.175	0.596	0.107	0.944	0.174	1.389
21	0.398	1.538	0.168	1.545					0.179	0.997	0.104	0.724	0.175	1.426
22	0.431	1.223	0.18	1.299					0.19	0.744	0.111	0.86	0.179	1.248
23	0.432	1.465	0.174	1.487					0.197	0.613	0.11	0.728	0.179	1.236
24	0.421	1.843	0.178	1.594					0.203	0.702	0.111	0.544	0.18	2.353
25	0.481	1.757	0.185	1.475					0.219	0.472	0.129	0.935	0.184	2.255
26	0.494	1.611	0.195	1.41					0.223	0.806	0.114	0.901	0.139	0.931
27	0.54	1.754	0.203	1.937					0.227	0.606	0.114	0.557	0.161	1.037
28	0.564	2.255	0.205	1.534					0.289	1.273	0.151	1.377	0.162	0.893
29	0.585	1.221	0.213	1.577					0.294	1.395	0.153	1.596	0.169	0.691
30			0.222	0.958					0.3	1.305	0.154	1.699	0.18	1.609
31			0.275	2.444							0.103	0.679	0.185	1.776
32											0.12	1.14	0.211	2.102
33											0.12	0.631	0.224	1.466
34											0.121	0.834	0.162	0.849
35											0.144	0.626	0.17	0.668
36											0.116	0.668	0.187	1.453
37											0.118	1.194	0.198	1.371
38											0.112	0.779	0.219	1.847
39											0.126	0.782	0.22	1.578
40											0.139	1.244	0.201	0.878
41											0.119	1.212	0.206	1.196
42											0.109	0.755	0.223	1.115
43											0.122	0.841	0.225	1.43
44											0.131	0.929	0.233	1.724
45											0.135	0.862	0.241	1.131
46											0.142	1.834	0.219	0.96
47											0.146	1.689	0.237	1.33
48											0.148	1.357	0.241	0.918
49											0.151	1.817	0.34	0.605
50											0.164	1.631	0.407	1.189
51											0.164	1.052		

Table 5.3.1.1. Western horse mackerel. Final assessment. Numbers-at-age (thousands).

	0	1	2	3	4	5	6	7	8	9	10	11+
1982	68205100	804597	2018380	3813230	560030	502385	410701	323757	50932.9	57107.8	65140.8	3211070
1983	523432	58704700	689078	1717690	3157070	471340	420163	342601	270452	42306.6	48769	2742930
1984	1533880	450522	50520300	590990	1447910	2667670	391450	320317	246012	216152	33360.5	2111230
1985	2764570	1320220	387768	43259300	504552	1212550	2157110	316189	240219	180183	172354	1601940
1986	3895300	2379490	1134810	329208	36674200	430131	1004850	1763520	260416	191755	149333	1439200
1987	5204280	3352710	2048040	976739	281916	30938400	362121	804446	1416060	200288	145396	1216920
1988	2000750	4479360	2885610	1762310	840687	239910	25801700	309768	653832	1134560	161498	1089700
1989	2116470	1721250	3830030	2478000	1514890	719502	188895	21334100	255380	525729	913562	1007040
1990	1847750	1821660	1481490	3296540	2113570	1286910	614357	149131	17177900	208632	397431	1491310
1991	3376740	1590370	1548990	1233350	2708470	1762160	1076770	518995	109241	13500400	145235	1315880
1992	6218310	2887250	1337710	1249990	1040180	2138460	1383970	858378	423167	70288.9	10488400	1034460
1993	7394680	5338330	2271970	1117670	1001150	843085	1603010	1073330	693335	346547	38743.5	8795820
1994	7765340	6364620	4493480	1867830	946462	803514	637783	1085310	789662	531151	267945	6586660
1995	4541700	6680270	5421710	3021740	1500290	765334	650128	512977	728208	580853	419315	4899100
1996	2512130	3906570	5596330	4230000	2206950	1091410	603960	475302	408446	399264	389435	3412210
1997	2165440	2152260	3344070	4205670	2842020	1726690	860059	472180	357858	302030	290646	2757800
1998	3696410	1859300	1750280	2446540	2937110	2065180	1259510	629801	287975	183241	157943	1569330
1999	4474880	3180840	1515420	1335360	1652410	2193900	1573740	938044	428349	172252	94385.2	976903
2000	4649920	3837810	2647260	1226670	985221	1175630	1652180	1157640	633662	232001	76181.5	549581
2001	19221600	4001630	3230080	2156880	1006900	781395	871904	1263970	831256	421739	142556	401980
2002	4045760	16489800	3379820	2551440	1715700	775306	578532	641954	870042	526373	266539	341464
2003	2954300	3469500	13765100	2797610	2042990	1359520	607520	433165	464929	627981	373894	426728
2004	1526300	2541080	2704460	11304400	2254230	1617290	1087630	469603	330527	354267	454453	589063
2005	963118	1293990	2056970	2224790	9289760	1869600	1296450	871333	363388	255154	259286	778958
2006	750974	827795	1047410	1611860	1627210	7502930	1545570	1046850	692776	272457	198920	793095
2007	1099860	644606	666663	864922	1348760	1332030	5992880	1277130	864453	555766	218597	797150
2008	1916170	942407	524934	543798	700432	1098330	1079860	4885160	1040180	713020	456919	836378
2009	796954	1620840	756721	422383	433608	562402	876953	868178	3923340	848723	579411	1052990
2010	267717	642082	1279530	598925	330550	342286	440862	693367	685519	3159600	680043	1311120
2011	329094	223960	479393	959411	440813	246777	252618	330001	517878	528898	2417440	1529510
2012	2298352[1]	282239	165661	356216	698917	326038	180301	187369	244196	396701	401552	3009290
2013		1946791	198455	117192	245422	491387	225510	127240	131818	179907	288811	2497230

1. Age 0 in 2012 is the geometric mean of the time-series 1983 to 2011

Table 5.3.1.2. Western horse mackerel. Final assessment. Fishing mortality-at-age.

	0	1	2	3	4	5	6	7	8	9	10	11+
1982	0.000	0.005	0.011	0.039	0.022	0.029	0.031	0.030	0.036	0.008	0.028	0.028
1983	0.000	0.000	0.004	0.021	0.018	0.036	0.121	0.181	0.074	0.088	0.129	0.129
1984	0.000	0.000	0.005	0.008	0.027	0.062	0.064	0.138	0.161	0.076	0.142	0.142
1985	0.000	0.001	0.014	0.015	0.010	0.038	0.051	0.044	0.075	0.038	0.059	0.059
1986	0.000	0.000	0.000	0.005	0.020	0.022	0.072	0.069	0.113	0.127	0.116	0.116
1987	0.000	0.000	0.000	0.000	0.011	0.032	0.006	0.057	0.072	0.065	0.073	0.073
1988	0.000	0.007	0.002	0.001	0.006	0.089	0.040	0.043	0.068	0.067	0.067	0.067
1989	0.000	0.000	0.000	0.009	0.013	0.008	0.086	0.067	0.052	0.130	0.103	0.103
1990	0.000	0.012	0.033	0.046	0.032	0.028	0.019	0.161	0.091	0.212	0.211	0.211
1991	0.007	0.023	0.064	0.020	0.086	0.092	0.077	0.054	0.291	0.102	0.195	0.195
1992	0.003	0.090	0.030	0.072	0.060	0.138	0.104	0.064	0.050	0.446	0.120	0.120
1993	0.000	0.022	0.046	0.016	0.070	0.129	0.240	0.157	0.116	0.107	0.144	0.144
1994	0.001	0.010	0.247	0.069	0.062	0.062	0.068	0.249	0.157	0.086	0.186	0.186
1995	0.001	0.027	0.098	0.164	0.168	0.087	0.163	0.078	0.451	0.250	0.294	0.294
1996	0.005	0.005	0.136	0.248	0.095	0.088	0.096	0.134	0.152	0.168	0.171	0.171
1997	0.002	0.057	0.163	0.209	0.169	0.165	0.162	0.344	0.519	0.498	0.514	0.514
1998	0.000	0.055	0.121	0.242	0.142	0.122	0.145	0.235	0.364	0.513	0.420	0.420
1999	0.004	0.034	0.061	0.154	0.190	0.134	0.157	0.242	0.463	0.666	0.517	0.517
2000	0.000	0.022	0.055	0.047	0.082	0.149	0.118	0.181	0.257	0.337	0.293	0.293
2001	0.003	0.019	0.086	0.079	0.111	0.151	0.156	0.223	0.307	0.309	0.317	0.317
2002	0.004	0.031	0.039	0.072	0.083	0.094	0.139	0.173	0.176	0.192	0.204	0.204
2003	0.001	0.099	0.047	0.066	0.084	0.073	0.107	0.120	0.122	0.173	0.157	0.157
2004	0.015	0.061	0.045	0.046	0.037	0.071	0.072	0.106	0.109	0.162	0.142	0.142
2005	0.001	0.061	0.094	0.163	0.064	0.040	0.064	0.079	0.138	0.099	0.119	0.119
2006	0.003	0.066	0.041	0.028	0.050	0.075	0.041	0.041	0.070	0.070	0.069	0.069
2007	0.005	0.055	0.054	0.061	0.055	0.060	0.054	0.055	0.043	0.046	0.044	0.044
2008	0.017	0.069	0.067	0.076	0.069	0.075	0.068	0.069	0.053	0.057	0.056	0.056
2009	0.066	0.086	0.084	0.095	0.086	0.093	0.085	0.086	0.066	0.072	0.069	0.069
2010	0.028	0.142	0.138	0.157	0.142	0.154	0.140	0.142	0.109	0.118	0.114	0.114
2011	0.004	0.152	0.147	0.167	0.152	0.164	0.149	0.151	0.117	0.125	0.121	0.121
2012	0.000	0.202	0.196	0.223	0.202	0.219	0.199	0.202	0.156	0.167	0.162	0.162

Table 5.3.1.3. Western horse mackerel. Final assessment. Stock summary table.

	R (age 0) (thousands)	SSB (tons)	TSB (tons)	Catch (tons)	Yield/SSB	F(1-3)	F(4-8)	F(1-10)
1982	68205100	1757500	2026211	61197	0.035	0.018	0.030	0.024
1983	523432	1718920	1976636	90442	0.053	0.008	0.086	0.067
1984	1533880	1553030	4044381	96744	0.062	0.004	0.091	0.068
1985	2764570	2540690	4901736	103843	0.041	0.010	0.044	0.035
1986	3895300	3245300	5155557	145999	0.045	0.002	0.059	0.054
1987	5204280	3816590	5086453	187338	0.049	0.000	0.036	0.032
1988	2000750	4334570	4986941	214729	0.050	0.003	0.049	0.039
1989	2116470	3969210	4751200	296037	0.075	0.003	0.045	0.047
1990	1847750	3376680	4132867	398645	0.118	0.031	0.066	0.085
1991	3376740	3206120	3913068	357288	0.111	0.036	0.120	0.101
1992	6218310	2628280	3182140	394793	0.150	0.064	0.083	0.117
1993	7394680	2452960	3027730	458628	0.187	0.028	0.142	0.105
1994	7765340	2070370	2744053	413022	0.199	0.109	0.120	0.120
1995	4541700	1593980	2368836	538131	0.338	0.096	0.189	0.178
1996	2512130	1452310	2293398	420942	0.290	0.130	0.113	0.129
1997	2165440	1250850	2094639	471700	0.377	0.143	0.272	0.280
1998	3696410	1050380	1611378	326443	0.311	0.139	0.202	0.236
1999	4474880	1002470	1463947	298076	0.297	0.083	0.237	0.262
2000	4649920	936161	1332253	196911	0.210	0.042	0.157	0.154
2001	19221600	654540	1137827	212090	0.324	0.061	0.190	0.176
2002	4045760	803772	1354238	194292	0.242	0.047	0.133	0.120
2003	2954300	897376	1988895	190183	0.212	0.071	0.101	0.105
2004	1526300	1104180	2322130	157627	0.143	0.051	0.079	0.085
2005	963118	1588190	2402837	181994	0.115	0.106	0.077	0.092
2006	750974	1608280	2061751	155094	0.096	0.045	0.055	0.055
2007	1099860	1490340	1796163	123408	0.083	0.057	0.053	0.053
2008	1916170	1621390	1907317	143106	0.088	0.071	0.067	0.066
2009	796954	1721220	2028638	183400	0.107	0.088	0.084	0.082
2010	267717	1393710	1742984	218143	0.157	0.146	0.137	0.136
2011	329094	1256400	1551752	199593	0.159	0.155	0.146	0.144
2012	2298352[1]	1058800	1272916	173141	0.164	0.207	0.195	0.193
2013		835853						

Note: the final estimate of SSB assumes the same F-at-age as in the preceding year

1. R(age 0) in 2011 is the geometric mean of the time series 1983 to 2010

Table 5.4.1. Western Horse Mackerel. Short term prediction: INPUT DATA

2013	Stock abundance	Natural mortality	Maturity ogive	Prop. Of F before spw.	Prop. Of M before spw.	Weights in the stock	Explotation pattern	Weights in the catch
0	2298352	0.15	0	0.45	0.45	0.000	0	0.046
1	1946791	0.15	0	0.45	0.45	0.040	0.20219	0.05
2	198455	0.15	0.05	0.45	0.45	0.068	0.19613	0.085
3	117192	0.15	0.25	0.45	0.45	0.082	0.22256	0.109
4	245422	0.15	0.7	0.45	0.45	0.109	0.2023	0.142
5	491387	0.15	0.95	0.45	0.45	0.146	0.21865	0.169
6	225510	0.15	1	0.45	0.45	0.169	0.19855	0.181
7	127240	0.15	1	0.45	0.45	0.186	0.20166	0.2
8	131818	0.15	1	0.45	0.45	0.199	0.15553	0.219
9	179907	0.15	1	0.45	0.45	0.221	0.16741	0.238
10	288811	0.15	1	0.45	0.45	0.230	0.16178	0.257
11	2497230	0.15	1	0.45	0.45	0.273	0.16178	0.307

2014	Stock abundance	Natural mortality	Maturity ogive	Prop. Of F before spw.	Prop. Of M before spw.	Weights in the stock	Explotation pattern	Weights in the catch
0	2298352	0.15	0	0.45	0.45	0.000	0	0.046
1	.	0.15	0	0.45	0.45	0.040	0.20219	0.05
2	.	0.15	0.05	0.45	0.45	0.068	0.19613	0.085
3	.	0.15	0.25	0.45	0.45	0.082	0.22256	0.109
4	.	0.15	0.7	0.45	0.45	0.109	0.2023	0.142
5	.	0.15	0.95	0.45	0.45	0.146	0.21865	0.169
6	.	0.15	1	0.45	0.45	0.169	0.19855	0.181
7	.	0.15	1	0.45	0.45	0.186	0.20166	0.2
8	.	0.15	1	0.45	0.45	0.199	0.15553	0.219
9	.	0.15	1	0.45	0.45	0.221	0.16741	0.238
10	.	0.15	1	0.45	0.45	0.230	0.16178	0.257
11	.	0.15	1	0.45	0.45	0.273	0.16178	0.307

2015	Stock abundance	Natural mortality	Maturity ogive	Prop. Of F before spw.	Prop. Of M before spw.	Weights in the stock	Explotation pattern	Weights in the catch
0	2298352	0.15	0	0.45	0.45	0.000	0	0.046
1	.	0.15	0	0.45	0.45	0.040	0.20219	0.05
2	.	0.15	0.05	0.45	0.45	0.068	0.19613	0.085
3	.	0.15	0.25	0.45	0.45	0.082	0.22256	0.109
4	.	0.15	0.7	0.45	0.45	0.109	0.2023	0.142
5	.	0.15	0.95	0.45	0.45	0.146	0.21865	0.169
6	.	0.15	1	0.45	0.45	0.169	0.19855	0.181
7	.	0.15	1	0.45	0.45	0.186	0.20166	0.2
8	.	0.15	1	0.45	0.45	0.199	0.15553	0.219
9	.	0.15	1	0.45	0.45	0.221	0.16741	0.238
10	.	0.15	1	0.45	0.45	0.230	0.16178	0.257
11	.	0.15	1	0.45	0.45	0.273	0.16178	0.307

Table 5.4.2. Western Horse Mackerel Short term prediction single option table. Catch constraint of 183 Kt in 2012 and F status quo for 2013 and 2014

Year:	2013	F multiplier	1.0124	Fbar:	0.1951				
Age	F	CatchNos	Yield	StockNos	Biomass	SSNos(Jan)	SSB(Jan)	SSNos(ST)	SSB(ST)
0	0	0	0	2298352	0	0	0	0	0
1	0.2047	335502	16775	1946791	77872	0	0	0	0
2	0.1986	33272	2828	198455	13495	9923	675	8482	577
3	0.2253	22017	2400	117192	9610	29298	2402	24745	2029
4	0.2048	42316	6009	245422	26751	171795	18726	146443	15962
5	0.2214	90863	15356	491387	71743	466818	68155	394975	57666
6	0.201	38230	6920	225510	38111	225510	38111	192560	32543
7	0.2042	21876	4375	127240	23667	127240	23667	108495	20180
8	0.1575	17869	3913	131818	26232	131818	26232	114785	22842
9	0.1695	26101	6212	179907	39759	179907	39759	155815	34435
10	0.1638	40602	10435	288811	66427	288811	66427	250778	57679
11	0.1638	351066	107777	2497230	681744	2497230	681744	2168371	591965
Total		1019714	183000	8748115	1075409	4128350	965898	3565449	835879

Year: 2014		F multiplier: 1		Fbar: 0.1927					
Age	F	CatchNos	Yield	StockNos	Biomass	SSNos(Jan)	SSB(Jan)	SSNos(ST)	SSB(ST)
0	0	0	0	2298352	0	0	0	0	0
1	0.2022	337130	16856	1978210	79128	0	0	0	0
2	0.1961	226372	19242	1365444	92850	68272	4643	58425	3973
3	0.2226	26022	2836	140049	11484	35012	2871	29608	2428
4	0.2023	13729	1949	80519	8777	56363	6144	48100	5243
5	0.2187	31476	5319	172115	25129	163510	23872	138515	20223
6	0.1986	56822	10285	338954	57283	338954	57283	289750	48968
7	0.2017	26991	5398	158753	29528	158753	29528	135517	25206
8	0.1555	11967	2621	89292	17769	89292	17769	77822	15487
9	0.1674	13903	3309	96927	21421	96927	21421	84026	18570
10	0.1618	18167	4669	130706	30062	130706	30062	113596	26127
11	0.1618	282937	86862	2035682	555741	2035682	555741	1769204	482993
Total		1045515	159347	8885003	929173	3173471	749334	2744563	649217

Year:	2015	F multiplier	1	Fbar:	0.1927				
Age	F	CatchNos	Yield	StockNos	Biomass	SSNos(Jan)	SSB(Jan)	SSNos(ST)	SSB(ST)
0	0	0	0	2298352	0	0	0	0	0
1	0.2022	337130	16856	1978210	79128	0	0	0	0
2	0.1961	230604	19601	1390971	94586	69549	4729	59517	4047
3	0.2226	179476	19563	965943	79207	241486	19802	204212	16745
4	0.2023	16452	2336	96490	10517	67543	7362	57640	6283
5	0.2187	10353	1750	56610	8265	53780	7852	45559	6652
6	0.1986	19957	3612	119047	20119	119047	20119	101765	17198
7	0.2017	40669	8134	239203	44492	239203	44492	204193	37980
8	0.1555	14968	3278	111686	22225	111686	22225	97339	19370
9	0.1674	9436	2246	65784	14538	65784	14538	57028	12603
10	0.1618	9808	2521	70566	16230	70566	16230	61329	14106
11	0.1618	220451	67678	1586105	433007	1586105	433007	1378478	376325
Total		1089303	147575	8978967	822315	2624747	590356	2267061	511309

Table 5.4.3. Western Horse Mackerel. Short term prediction; single area management option table. OPTION: Catch constraint 183 Kt in 2013.

2013				
Biomass	SSB	FMult	FBar	Landings
1075409	835879	1.0124	0.1951	183000

2014					2015			
TSB	SSB	FMult	FBar	Landings	Biomass	SSB	SSB	TAC
929173	700423	0	0	0	966244	654682	-7%	-100%
.	695125	0.1	0.0193	17203	950662	638681	-9%	-91%
.	689866	0.2	0.0385	34110	935357	623074	-11%	-81%
.	684648	0.3	0.0578	50728	920325	607853	-13%	-72%
.	679469	0.4	0.0771	67060	905559	593007	-15%	-63%
.	674330	0.5	0.0963	83113	891056	578528	-17%	-55%
.	672592	0.534	0.1029	88508	886184	573686	-17%	-52%
.	669230	0.6	0.1156	98890	876811	564405	-19%	-46%
.	665431	0.675	0.1301	110546	866294	554042	-20%	-40%
.	664169	0.7	0.1349	114398	862819	550630	-21%	-37%
.	659147	0.8	0.1541	129640	849075	537195	-23%	-29%
.	654163	0.9	0.1734	144621	835576	524091	-25%	-21%
.	653667	0.91	0.1753	146105	834239	522798	-25%	-20%
.	650697	0.97	0.1869	154956	826269	515110	-26%	-15%
.	649217	1	0.1927	159347	822315	511309	-27%	-13%
.	644309	1.1	0.2119	173820	809291	498842	-29%	-5%
.	641382	1.16	0.2235	182385	801587	491510	-30%	0%
.	639438	1.2	0.2312	188047	796497	486682	-31%	3%
.	634604	1.3	0.2505	202030	783930	474821	-34%	10%
.	631722	1.36	0.262	210305	776498	467845	-35%	15%
.	629807	1.4	0.2697	215775	771587	463252	-36%	18%
.	625047	1.5	0.289	229285	759462	451967	-38%	25%
.	620323	1.6	0.3083	242565	747552	440960	-41%	33%
.	615635	1.7	0.3275	255619	735853	430223	-43%	40%
.	610983	1.8	0.3468	268450	724361	419750	-46%	47%
.	606366	1.9	0.3661	281063	713073	409534	-48%	54%
.	601785	2	0.3854	293461	701985	399570	-51%	60%

Figure 5.1.3.1. Western horse mackerel. Catch by ICES Division for 1982-2012

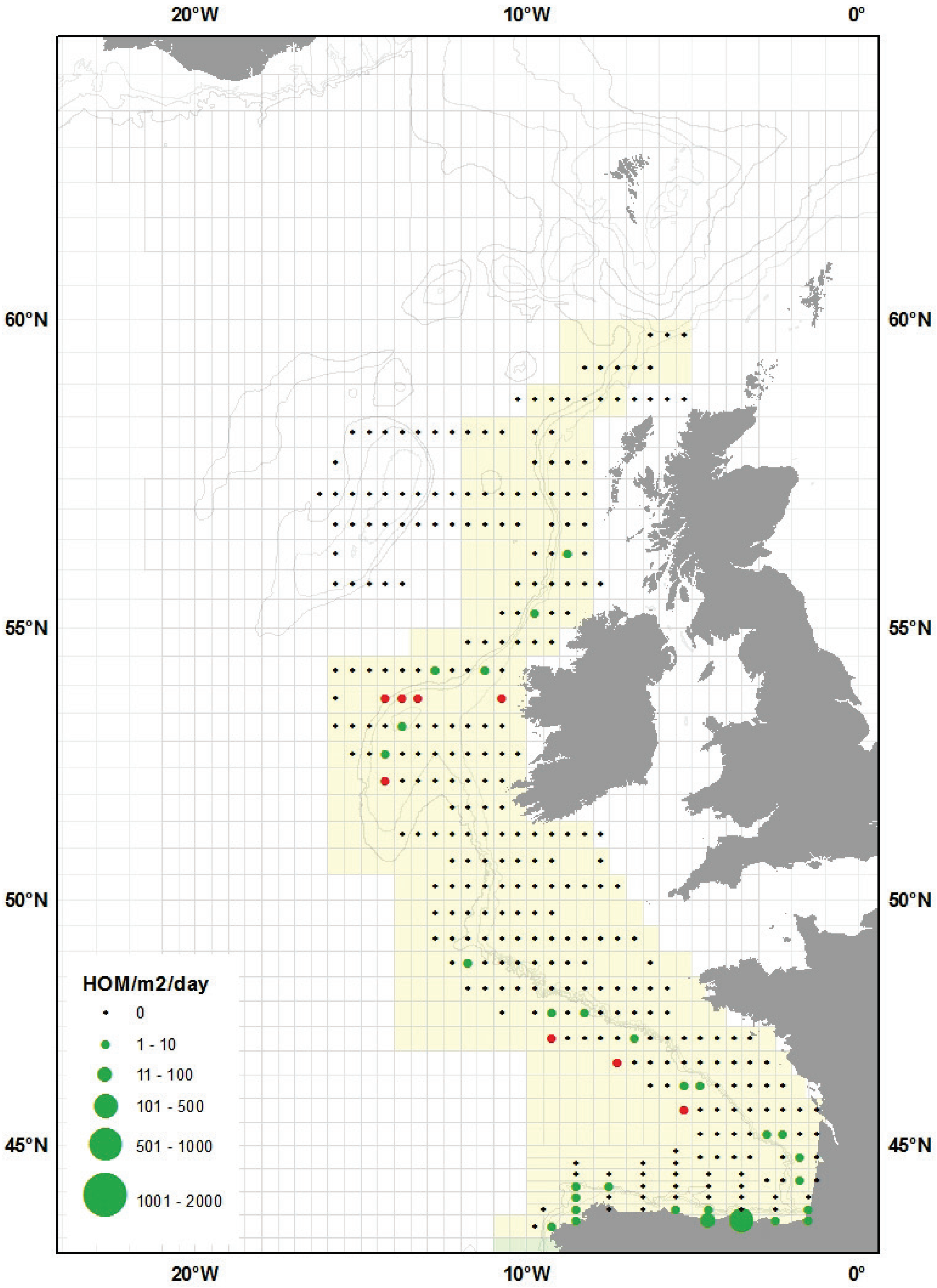

Figure 5.2.1.1: Horse mackerel egg production by half rectangle for period 2 (19th February – 27 th March). Filled green circles represent observed values, filled red circles represent interpolated values, black crosses represent observed zeroes, and red crosses interpolated zeroes.

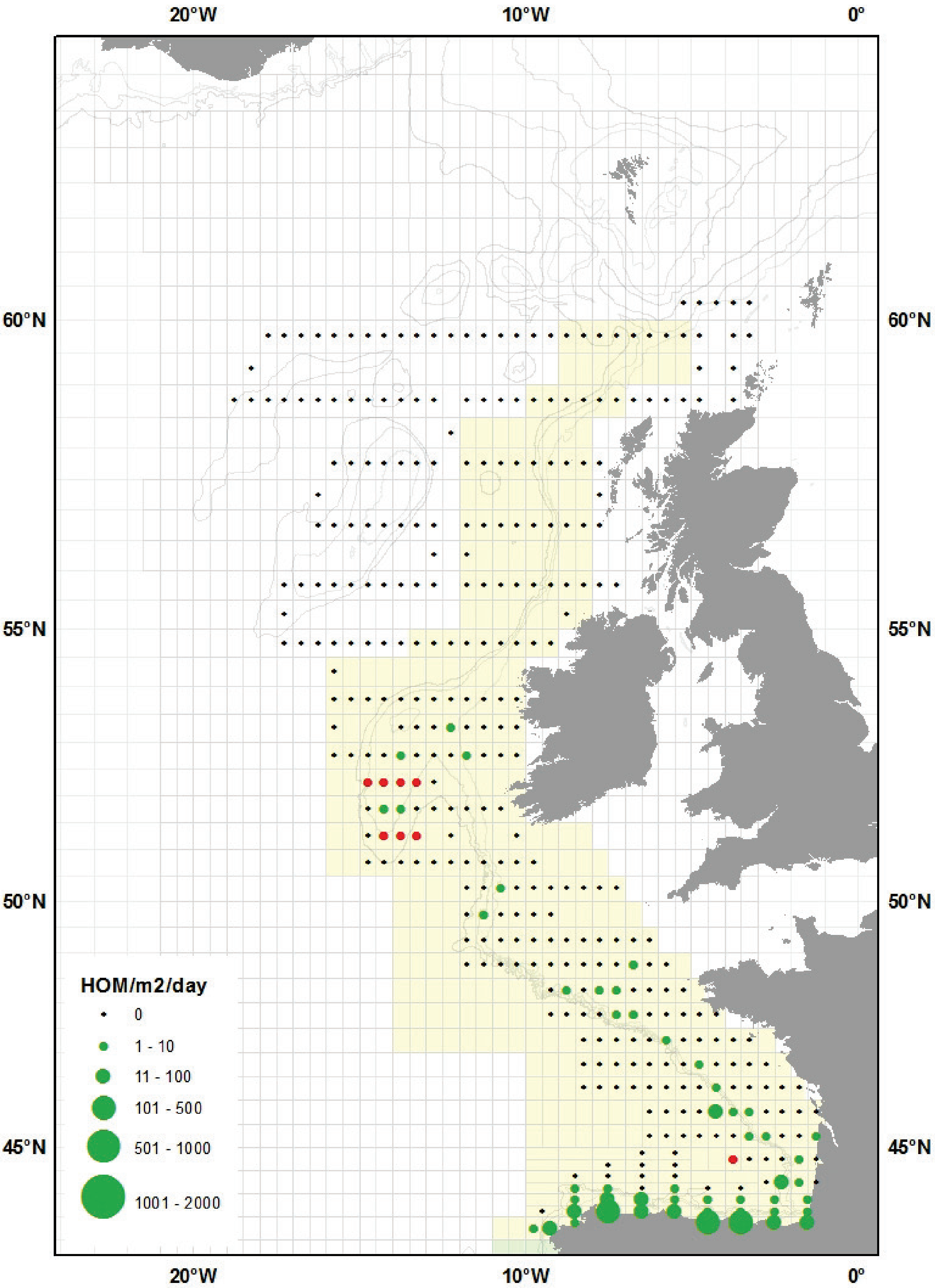

Figure 5.2.1.2: Horse mackerel egg production by half rectangle for period 3 (28th March – 6th May). Filled green circles represent observed values, filled red circles represent interpolated values, black crosses represent observed zeroes, red crosses interpolated zeroes.

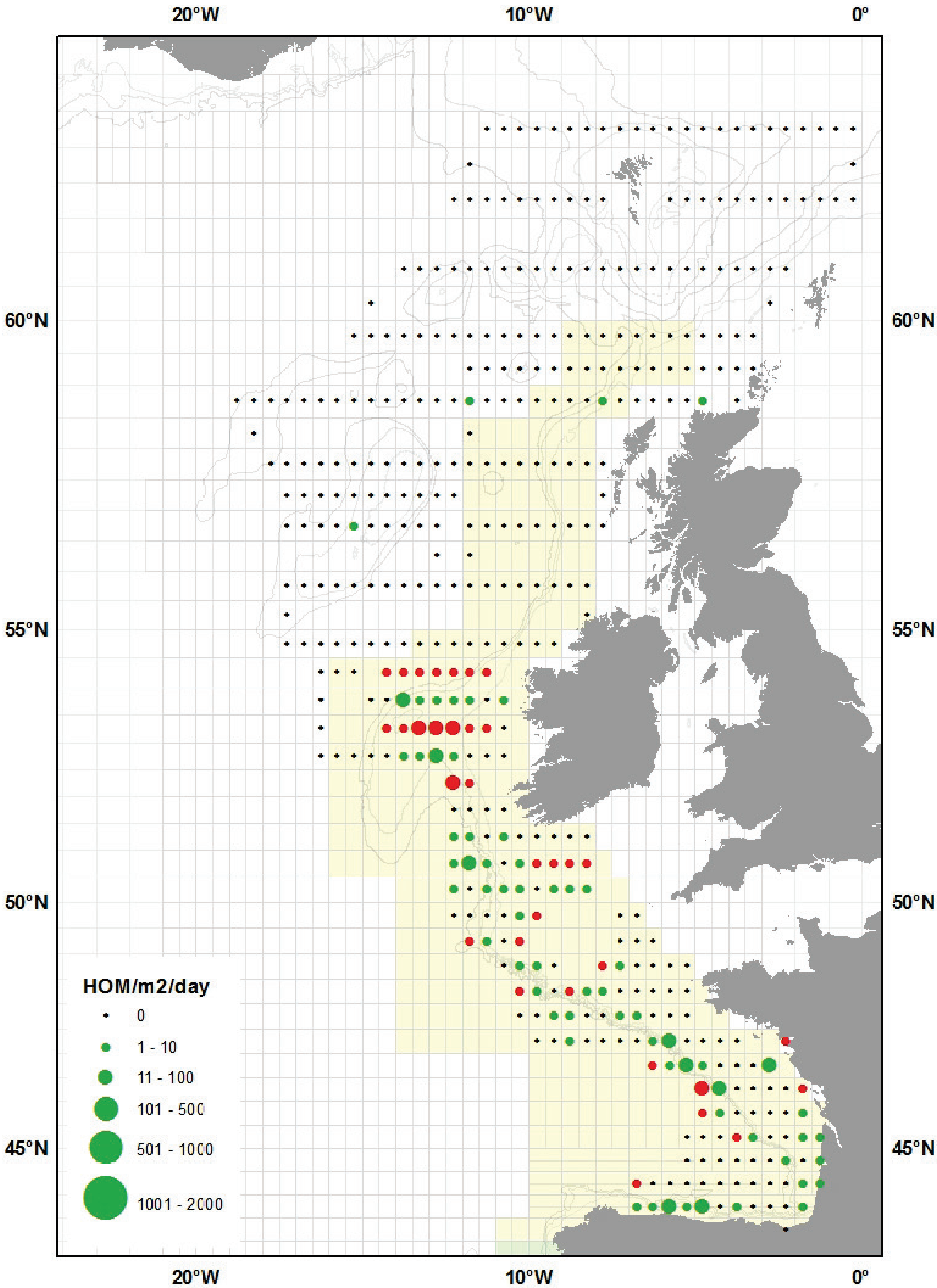

Figure 5.2.1.3: Horse mackerel egg production by half rectangle for period 4 (7th May – 3rd June). Filled green circles represent observed values, filled red circles represent interpolated values, black crosses represent observed zeroes, red crosses interpolated zeroes.

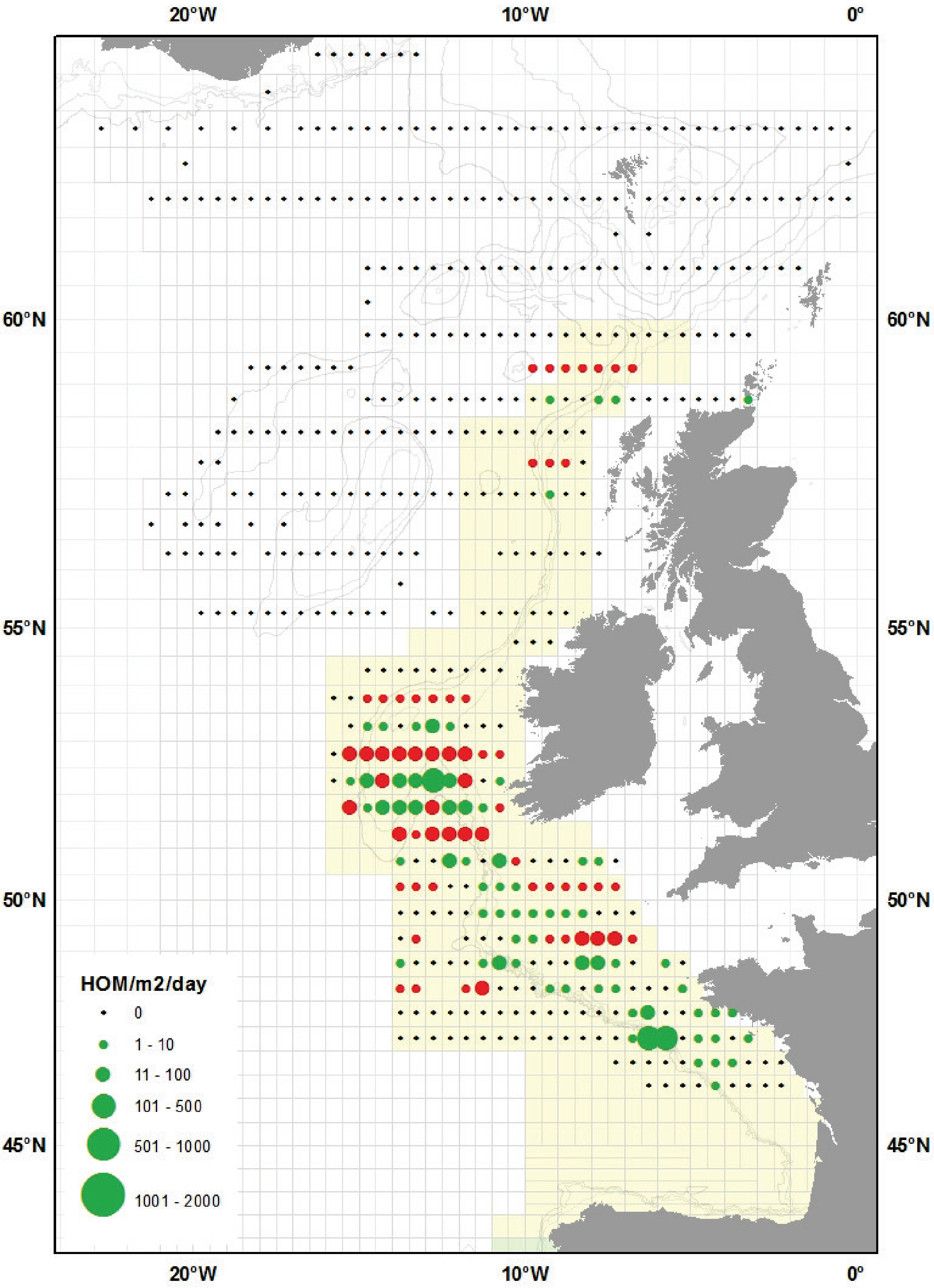

Figure 5.2.1.4: Horse mackerel egg production by half rectangle for period 5 (4th June – 26th June). Filled green circles represent observed values, filled red circles represent interpolated values, black crosses represent observed zeroes, and red crosses interpolated zeroes.

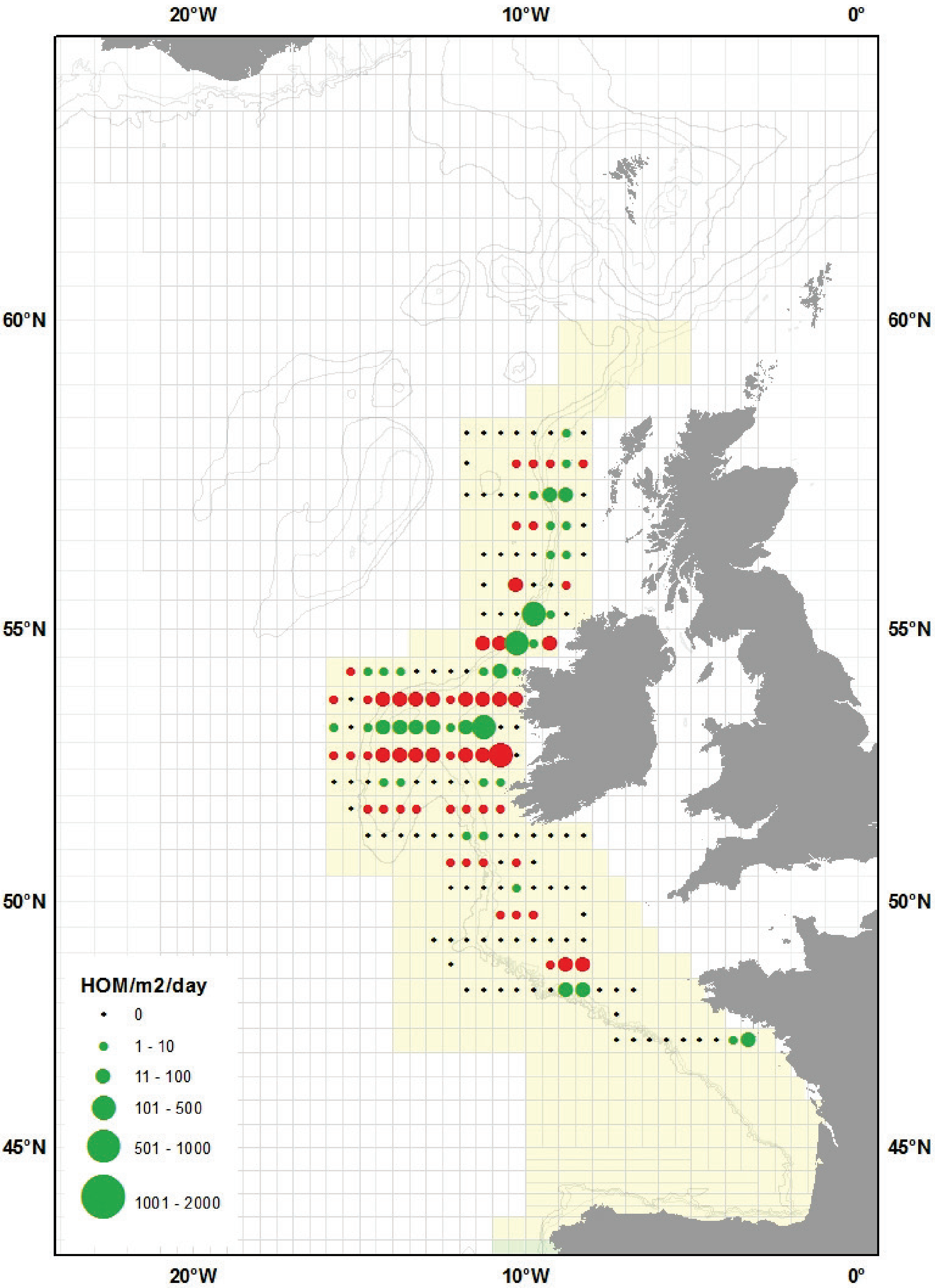

Figure 5.2.1.5: Horse mackerel egg production by half rectangle for period 6 (15th July – 31st July). Filled green circles represent observed values, filled red circles represent interpolated values, black crosses represent observed zeroes, and red crosses interpolated zeroes.

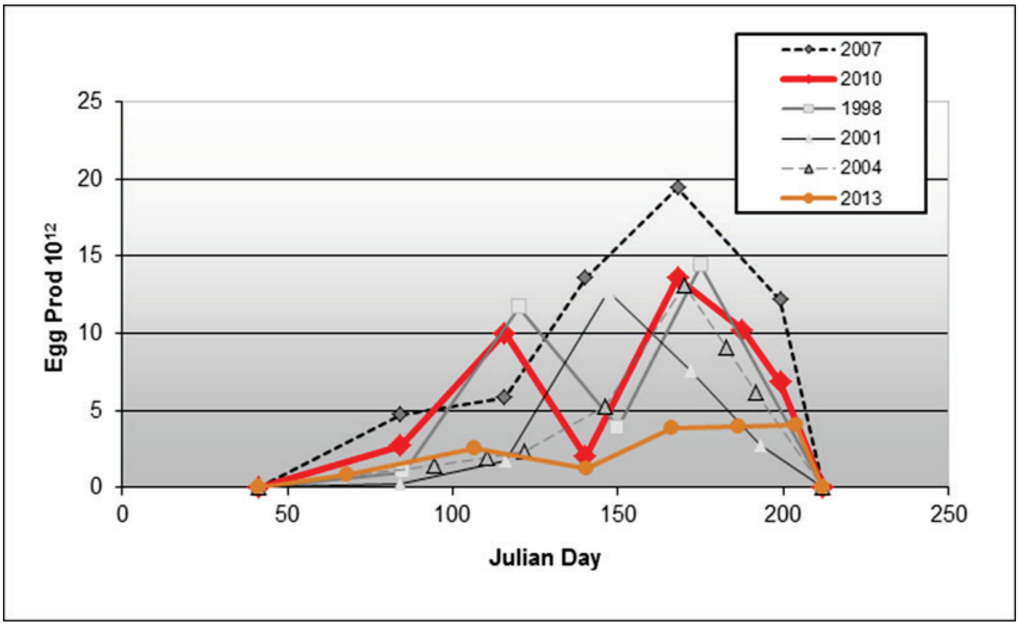

Figure 5.2.1.6: Western horse mackerel. Provisional annual egg production curve for western horse mackerel. The curves for 1998, 2001, 2004, 2007 and 2010 are included for comparison.

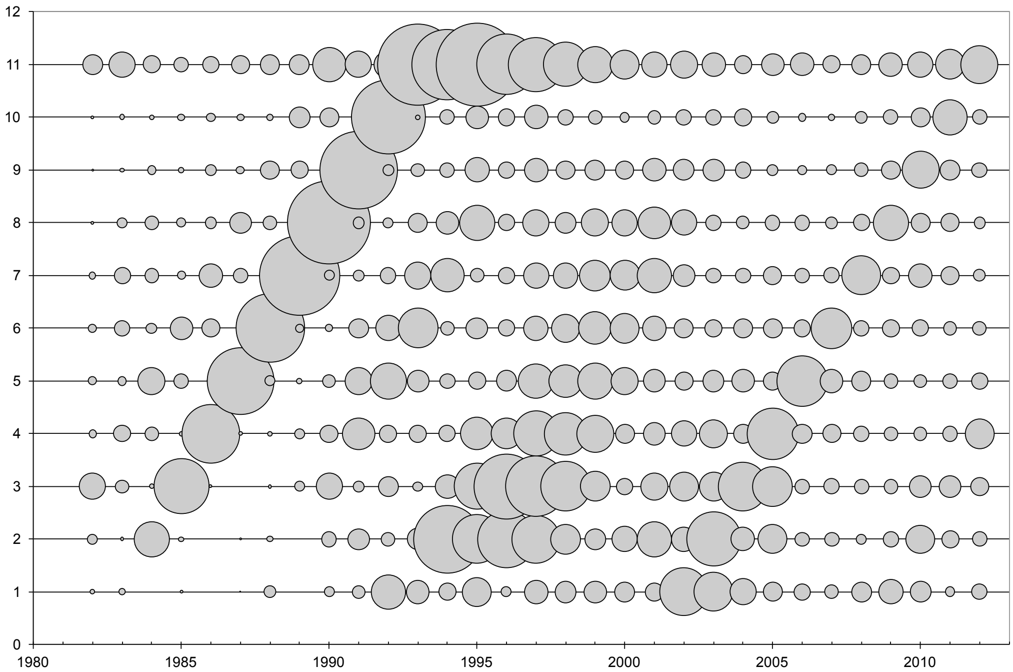

Figure 5.2.4.1: Western horse mackerel. Catch-at-age matrix, expressed as numbers (thousands). The area of bubbles is proportional to the catch number. Note that age 11 is a plus group.

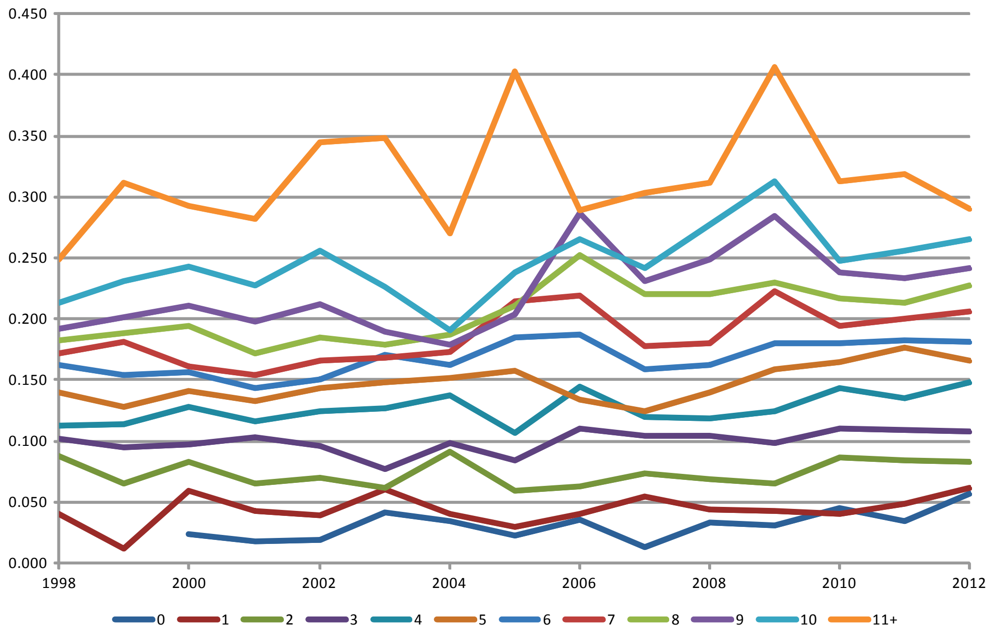

Figure 5.2.5.1: Western horse mackerel. Weight in the catch by year.

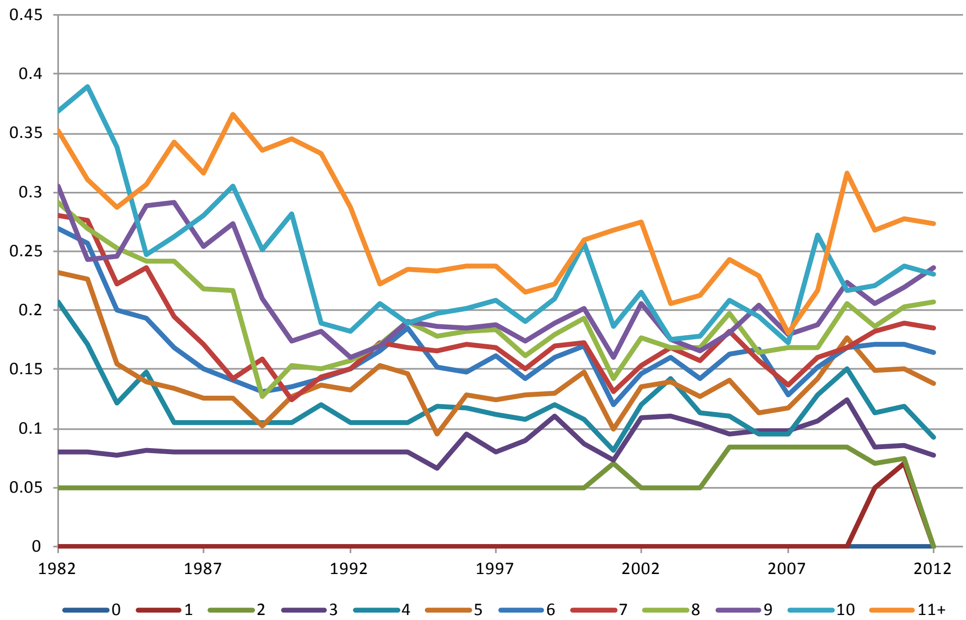

Figure 5.2.5.2: Western horse mackerel. Weight in the stock by year.

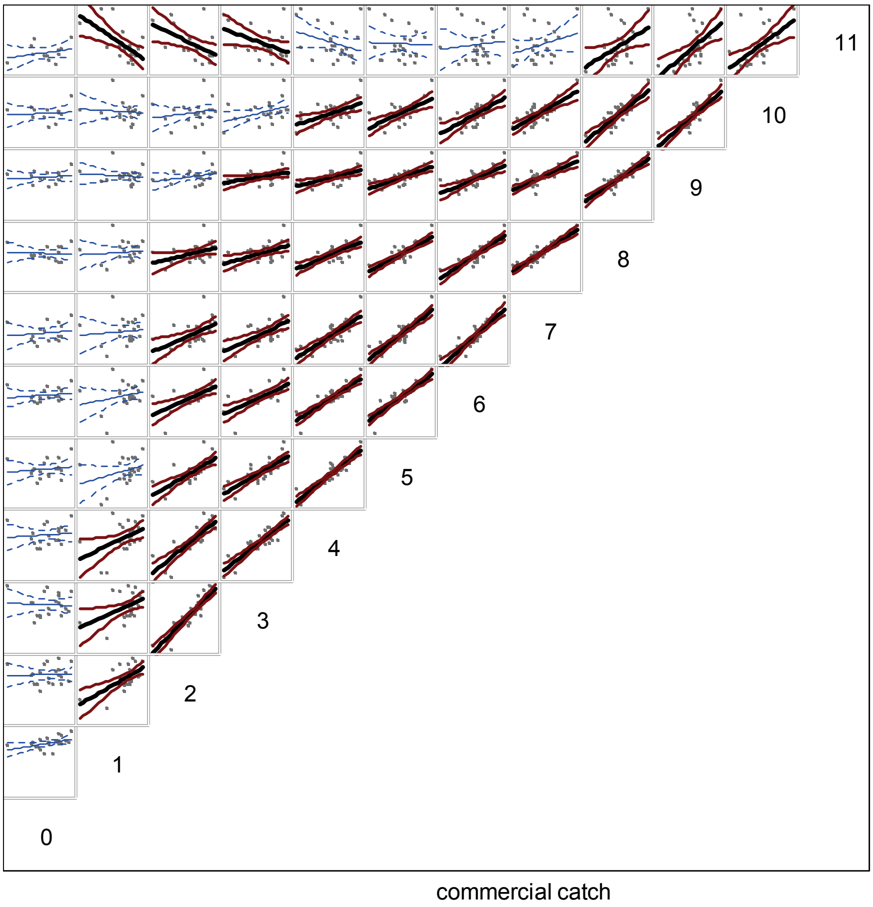

Figure 5.2.9.1: Western horse mackerel. Data exploration. Within-cohort consistency in the catch-at-age matrix, shown by plotting the log-catch of a cohort at a particular age against the log-catch of the same cohort at subsequent ages. Thick lines represent a significant (p<0.05) regression and the curved lines are approximate 95% confidence intervals.

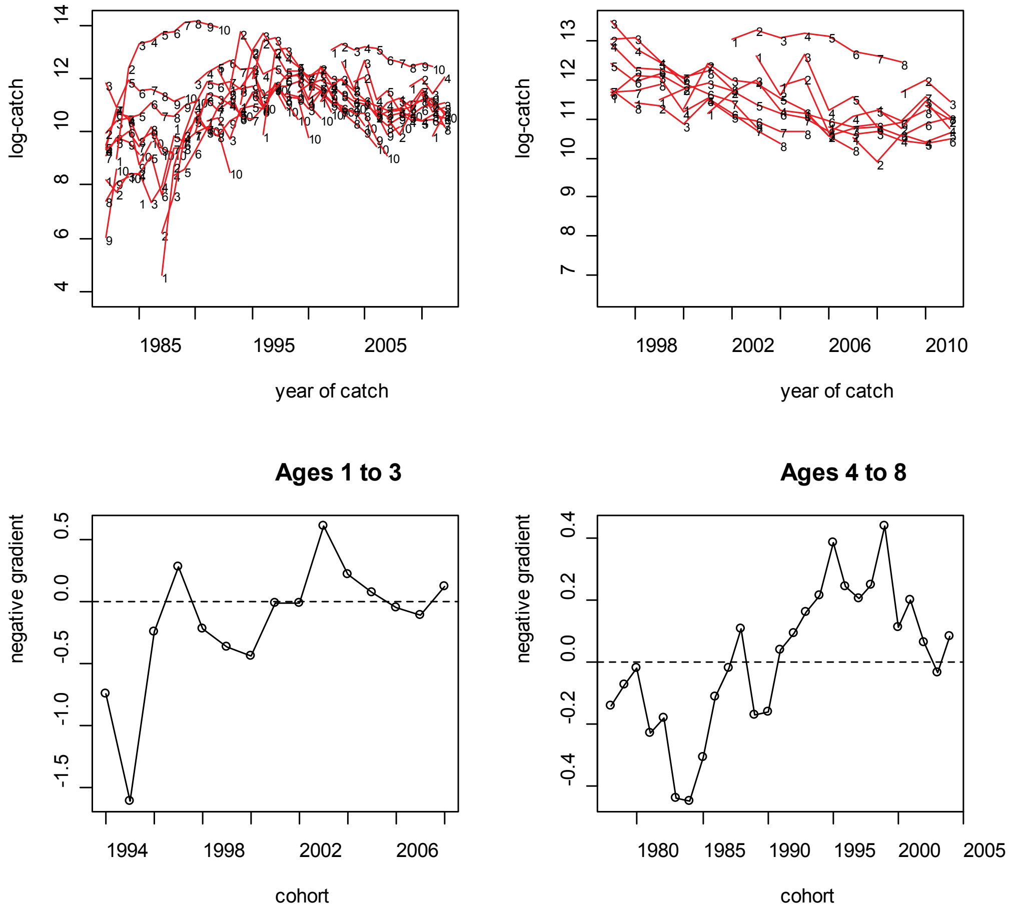

Figure 5.2.9.2: Western horse mackerel. Data exploration. Log-catch cohort curves (top row shows the full time series on the left, and the most recent period for ages 1-8 on the right) and the associated negative gradients for each cohort across the reference fishing mortality of ages 1-3 (bottom left and 4-8 (bottom right).

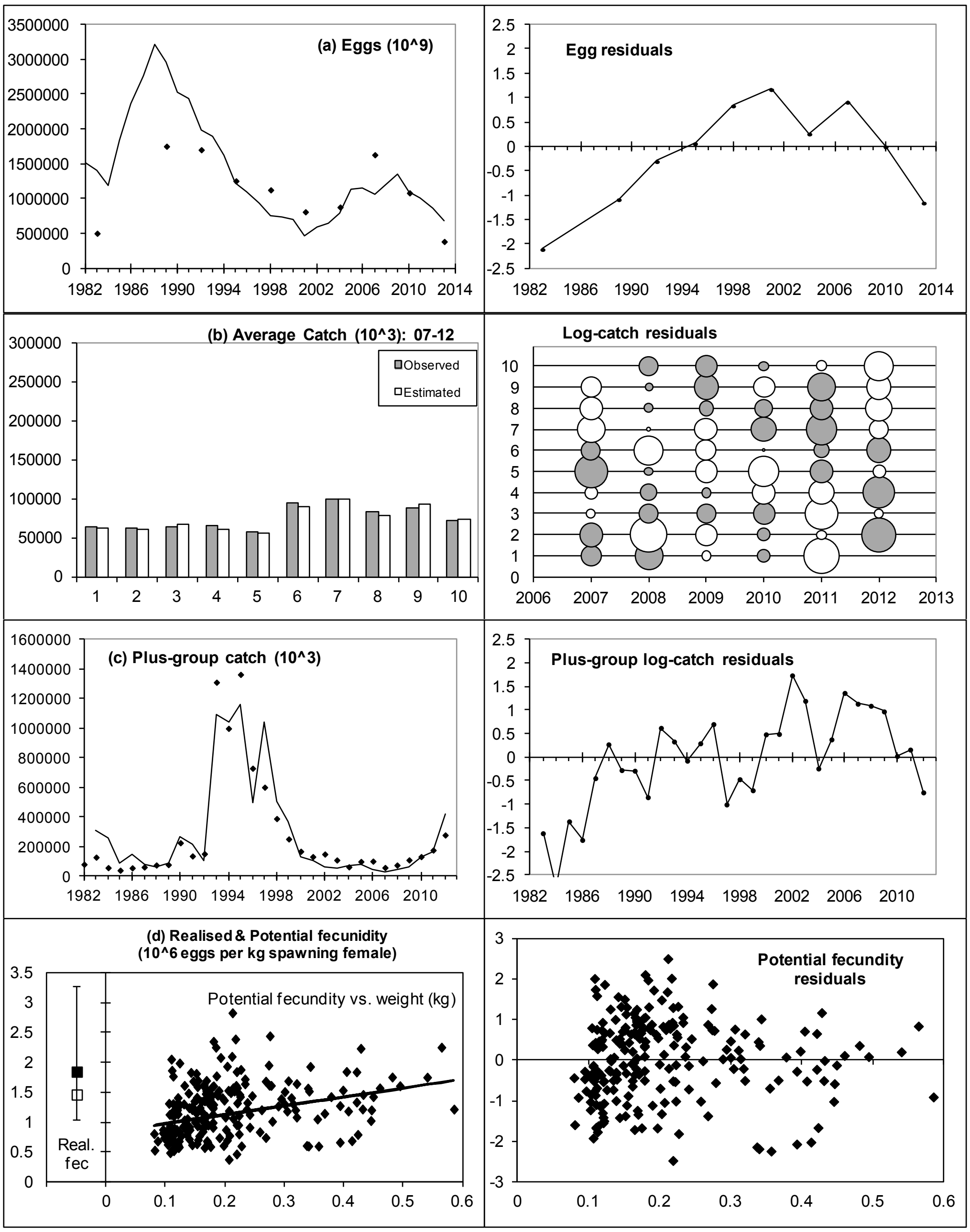

Figure 5.2.10.1: Western horse mackerel. SAD model with 2007-2012 separable window. Model fits to data for the five components of the likelihood, corresponding to (a) the egg estimates, (b) the catches in the separable period, (c) to the catches in the plus-group, and (d) population-mean realised fecundity (left of y-axis) and potential fecundity (right of y-axis). The left-hand column of plots shows the actual fit to the data (average catches are shown in (b) for ease of presentation),

and the right-hand column normalised residuals, of the form: ln X – ln $\hat{X}$ / σ. In the residual plot for (b), the area of a bubble reflects the size of the residual, with the maximum absolute size given in the top right of the plot. In the residual plot for (d), only the potential fecundity residuals are shown (there is only one residual for the population-mean realised fecundity). The final SSB estimate assumes the same fishing mortality as in the previous year.

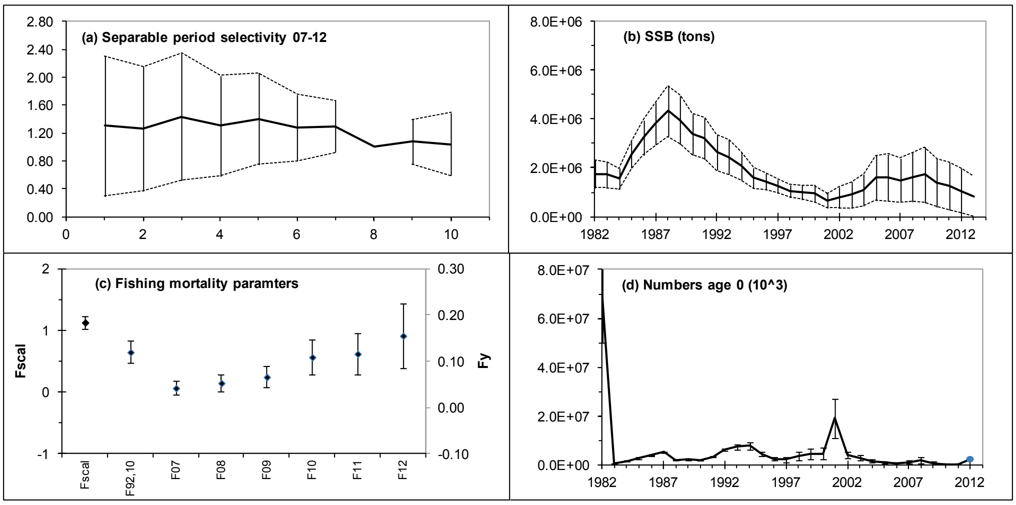

Figure 5.2.10.2: Western horse mackerel. Model with 2007-2012 separable window. Plots of (a) the selectivity pattern, (b) the SSB trajectory, (c) fishing mortality parameters (the scaling parameter F_{scal}, fishing mortality at age 10 in 1992, $F_{92,10}$, and the fishing mortality year effects for the separable period, F_y), and (d) numbers at age 0. The error bars are two standard deviations (indicating roughly 95% confidence bounds). The final SSB estimate assumes the same fishing mortality as in the previous year.

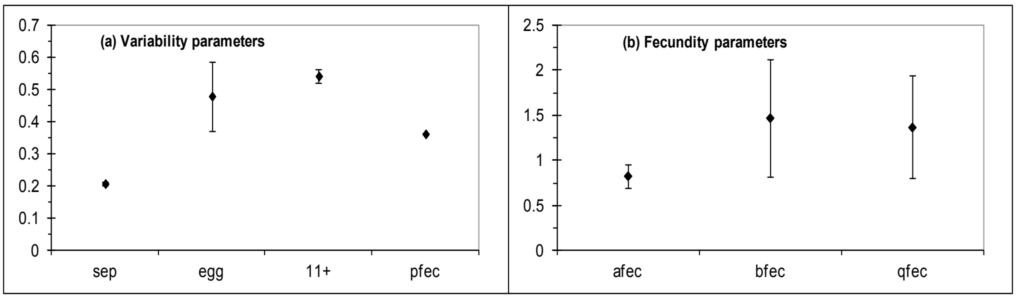

Figure 5.2.10.3: Western horse mackerel. Model with 2007-2012 separable window. Estimates for some key parameters, with (a) corresponding to variability parameters, plotted as standard deviations, for four components of the likelihood (σ_{sep}, σ_{egg}, σ_{11+} and σ_{pfec}), and (b) the fecundity parameters a_{fec}, b_{fec}, q_{fec}. The error bars are two standard deviations (indicating roughly 95% confidence bounds).

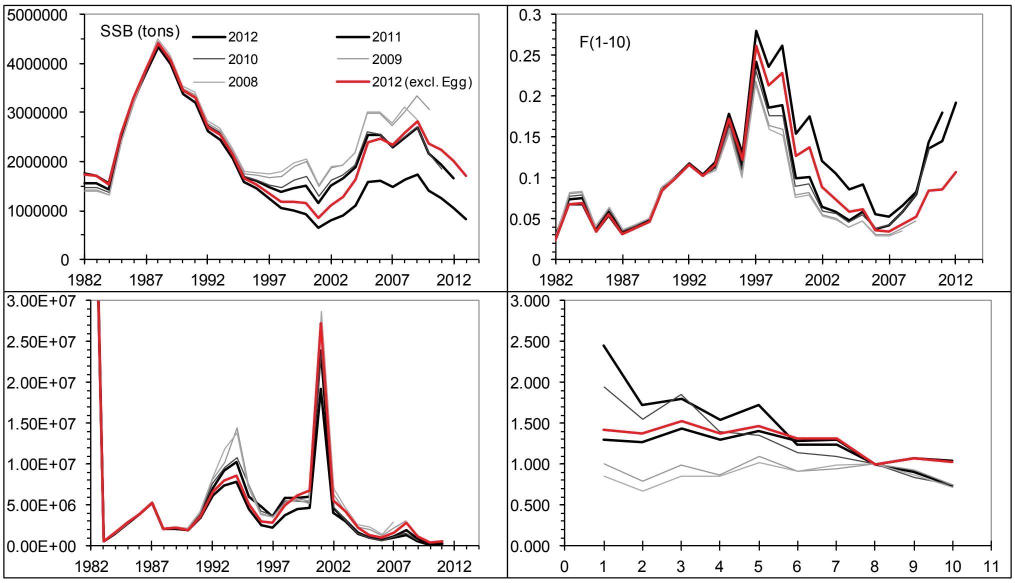

Figure 5.2.10.4: Western horse mackerel. 5-year retrospective bias for the case where the length of the separable window is kept at 6 years (the year shown is the final year shown of the window). For comparison purposes the 2009 assessment is shown with the exclusion of the 2013 egg estimate. Trajectories of SSB, F(1-10), Recruitment (age 0) and selectivity-at-age.

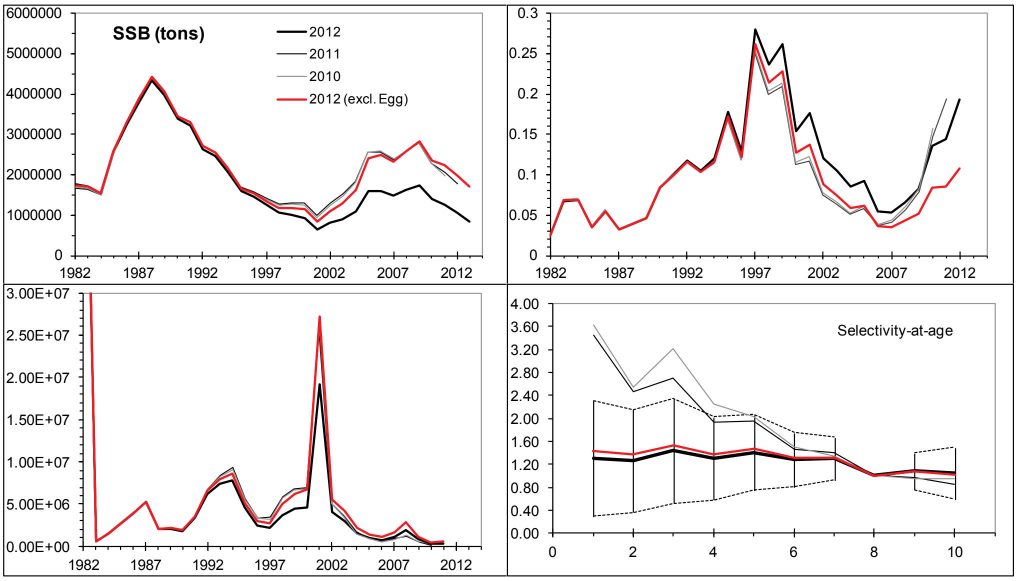

Figure 5.2.10.5: Western horse mackerel. 2-year retrospective bias for the case where the starting year of the separable window is kept at 2007, so that the window decreases in length as more years are dropped (the year shown is the final year of the window). For comparison purposes the 2013 assessment is shown with the exclusion of the 2013 egg estimate. Trajectories of SSB, F(1-10), recruitment (age 0) and selectivity-at-age including confidence bounds from the 2013 assessment.

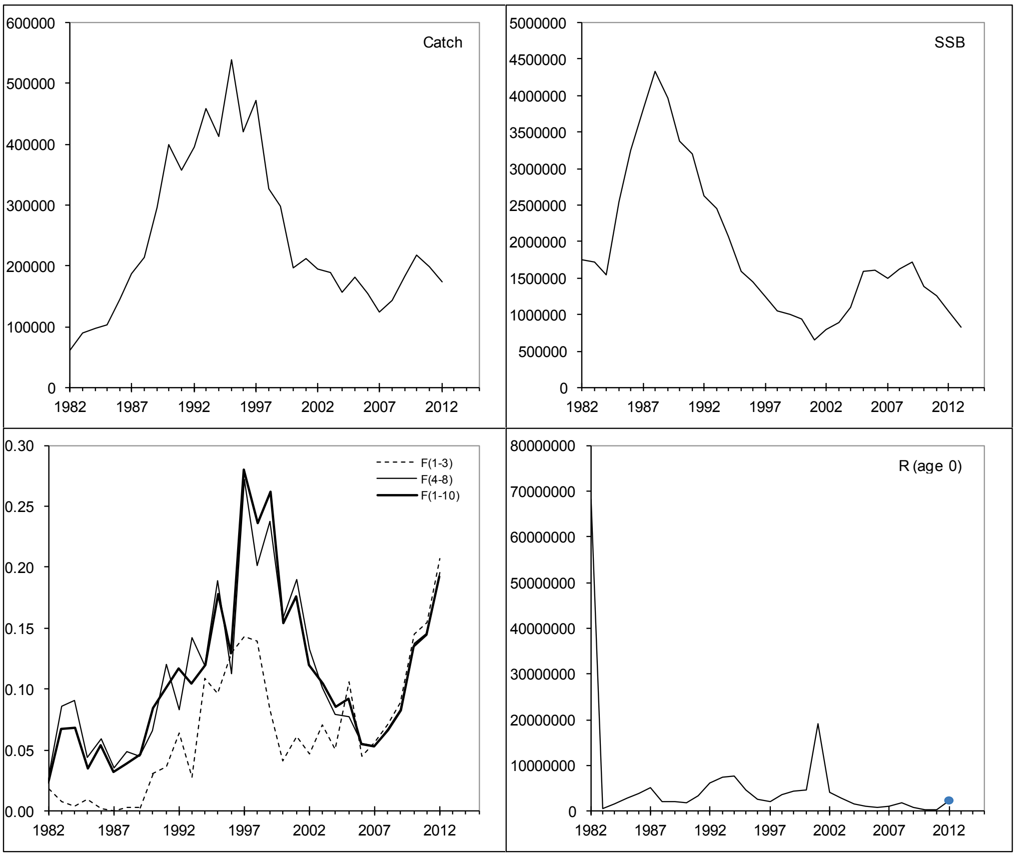

Figure 5.3.1.1: Western horse mackerel. Final assessment. stock summary. Plots of catch, SSB, recruitment (age 0) and fishing mortality (average for 1-3, 4-8 and 1-10). SSB and catch are in tons, and recruitment is in thousands. The final SSB estimate assumes the same fishing mortality as in the previous year. Recruitment in 2012 is the geometric mean of the time series excluding 1982.

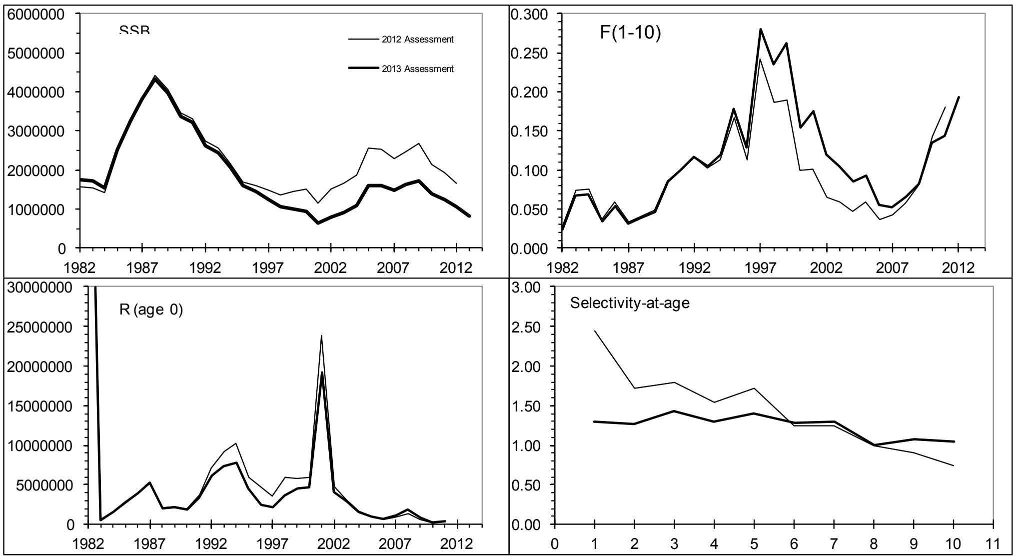

Figure 5.6.1: Western horse mackerel. Comparison of the final assessment this year with that of last year and 2012 assessment with provision 2013 egg survey estimate. Plots of SSB, recruitment (age 0), fishing mortality (average for ages 1-10) and selectivity-at-age for the separable period (2006-2011 for the 2012 assessment, and 2007-2012 for the 2013 assessment). SSB values are in tons, and recruitment is in thousands.

6 Northeast Atlantic Boarfish (*Capros aper*)

The boarfish (*Capros aper*, Linnaeus) is a deep bodied, laterally compressed, pelagic shoaling species distributed from Norway to Senegal, including the Mediterranean, Azores, Canaries, Madeira and Great Meteor Seamount (Blanchard and Vandermeirsch, 2005).

Boarfish is targeted in a pelagic trawl fishery for fish meal, to the southwest of Ireland. The boarfish fishery is conducted primarily in shelf waters and the first landings were reported in 2001. Landings were at very low levels from 2001-2005. The main expansion period of the fishery was 2006-2010 when unrestricted landings increased from 2 772 t to 137 503 t. A restrictive TAC of 33 000 t was implemented in 2011. In 2011, ICES was asked by the European Commission to provide advice for 2012. In 2013, ICES is considering this stock for the third time.

An analysis of bottom trawl survey data suggests a continuity of distribution spanning ICES Subareas IV, VI, VII, VIII and IX (Figure 6.1). Isolated small occurrences appear in the North Sea (ICES Subarea IV) in some years indicating spill-over into this region. A hiatus in distribution was suggested between ICES Divisions VIIIc and IXa as boarfish were considered very rare in northern Portuguese waters but abundant further south (Cardador and Chaves, 2010), however it is unclear if this suggested hiatus represents a true stock separation. Based on these data, a single stock is considered to exist in ICES Subareas IV, VI, VII, VIII and IXa. This distribution is broader than the current EC TAC area: VI, VII and VIII and for the purposes of assessment in 2013 only data from these areas were utilised. A dedicated study on the stock structure of boarfish within the Northeast Atlantic and Mediterranean Sea will commence in October 2013, the results of which will feed into future assessments.

6.1 The Fishery

6.1.1 Advice and management applicable to 2011, 2012 and 2013

In 2011 a TAC was set for this species for the first time, covering ICES Subareas VI, VII and VIII. This TAC was set at 33 000 t. Before 2010, the fishery was unregulated. In October 2010, the European Commission notified national authorities that under the terms of Annex 1 of Regulation 850/1998, industrial fisheries for this species should not proceed with mesh sizes of less than 100 mm. In 2011, the European Parliament voted to change Regulation 850/1998 to allow fishing using mesh sizes ranging from 32 to 54 mm.

For 2012, ICES advised that catches of boarfish should not increase, based on precautionary considerations. As supporting information, ICES noted that it would be cautious that landings did not increase above 82 000 t, the average over the period 2008-2010, during which the stock did not appear to be overexploited. In 2012 the TAC was set at 82 000 t by the Council of the European Union.

For 2013, ICES advised that catches of boarfish should not be more than 82,000 t. This was based on applying a harvest ratio of 12.2% ($F_{0.1}$, as an F_{msy} proxy). For 2013, the TAC was set at 82 000 t by the Council of the European Union.

By-catch of boarfish in the horse mackerel pelagic fishery is regulated by a provision in the TAC for the latter species. This allows a certain percentage of boarfish, and other species, to be retained and deducted from the horse mackerel quota.

In 2010, an interim management plan was proposed by Ireland, which included a number of measures to mitigate potential bycatch of other TAC species in the boarfish fishery. A closed season from the 15th March to 31st August was proposed, as anecdotal evidence suggests that mackerel and boarfish are caught in mixed aggregations during this period. A closed season was proposed in ICES Division VIIg from 1st September to 31st October, in order to prevent catches of Celtic Sea herring, which is known to form feeding aggregations in this region at these times. Finally, if catches of a species covered by a TAC, other than boarfish, amount to more than 5% of the total catch by day by ICES statistical rectangle, then fishing must cease in that rectangle.

In August 2012 the executive committee of the Pelagic RAC approved a long term management plan for boarfish. The management plan has not yet been evaluated by ICES.

Since 2011, there has been a provision for bycatch of boarfish (also whiting, haddock and mackerel) to be taken from the western and North Sea horse mackerel EC quotas. These provisions are shown in the text table below. The effect of this is that up to the value indicated of these 4 species combined may be landed legally and subtracted from quotas for horse mackerel.

Year	North Sea (t)	Western (t)
2011	2031	7779
2012	2148	7829
2013	1702	7799

6.1.2 The fishery in recent years

The first landings of boarfish were reported in 2001. Landings fluctuated between 100 and 700 t per year up to 2005 (Table 6.1.2.1). In 2006 the landings began to increase considerably as a target fishery developed. Cumulative landings since 2001 are now in excess of 380 000 t. The fishery targets dense shoals of boarfish from September to March. Catches are generally free from bycatch from September to February. From March onwards a bycatch of mackerel can be found in the catches and the fishery generally ceases at this time. Information on the bycatch of other species in the boarfish fishery is sparse, though thought to be minimal. The fishery uses typical pelagic trawl nets with mesh sizes ranging from 32 to 54 mm. Preliminary information suggests that only the smallest boarfish escape this gear.

From 2001 to 2006 only Ireland reported landings of boarfish. In 2007 UK-Scotland reported landings of less than 1 000 t. Scottish landings peaked at 9 241 t in 2010. Denmark joined the fishery in 2008 and landed 3 098 t. Danish landings then increased to 39 805 t in 2010. In all years the vast majority of catches have come from ICES Division VIIj (Figure 6.2 and Tables 6.1.2.2 and 6.1.2.3). Since 2011 landings have been regulated by TAC.

Previous to the development of the target fishery, boarfish was a discarded bycatch in pelagic fisheries for mackerel in ICES Subareas VII and VIII. A study by Borges *et al*. (2008) found that boarfish may account for as much as 5% of the total catch of Dutch pelagic freezer trawlers. Boarfish are also discarded in whitefish fisheries, particularly by Spanish demersal trawlers (Tables 6.1.2.1 and 6.1.2.4).

6.1.3 The fishery in 2012

In 2012, 80 720 t were landed. Ireland continued to be the main participant (55 949 t), with Denmark taking 19 888 t and Scotland 4 884 t. Forty Irish registered fishing vessels reported landings of boarfish with the majority made in Q1 (33 799t) and Q4 (18 091t). The Q3 landings of 4 059t were all made in September. Five Scottish pelagic vessels reported landings of boarfish, which were in Q3 (1 537t) and Q4 (3 347t). The number of Danish vessels participating in the fishery is unknown, however landings were reported in Q1 (16 523t), Q2 (208 t) and Q4 (3 157t).

6.1.4 Regulations and their effects

In 2010, the fishery finished early when the European Commission notified member states that mesh sizes of less than 100 mm were illegal. However, in 2011, the European Parliament voted to change Regulation 850/1998 to allow fishing for boarfish using mesh sizes ranging from 32 to 54 mm. The TAC (33 000 t) that was introduced in 2011 significantly reduced landings.

6.1.5 Changes in fishing technology and fishing patterns

The expansion of the fishery in the mid 2000s was associated with developments in the pumping and processing technology for boarfish catches. These changes made it easier to pump boarfish ashore. Efforts are underway to develop a human consumption market and fishery for boarfish. To date the majority of boarfish landings by Danish, Irish and Scottish vessels have been made into Skagen, Denmark and Fuglafjørður, Faroe Islands to be processed into fishmeal. A small number of Irish vessels have landed into Killybegs and Castletownbere, Ireland. These landings into Irish ports are expected to increase with the development of a human consumption fishery.

6.1.6 Discards

Discard data were available from Dutch and German pelagic freezer trawlers (areas not specified) and from Irish, Spanish and Portuguese demersal fleets (Prista *et al.*, WD 2013; Valeiras *et al.*, WD 2012; van Overzee and van Helmond, 2013). The Portuguese data relate to Division IXa and are not relevant to this stock. Table 6.1.2.4 shows available data.

Discards were not obtained from UK or French freezer trawlers, though discard patterns in these fleets are likely to be similar to the Dutch fleet. It is to be expected that discarding occurred before 2003, in demersal fisheries, however it is difficult to predict what the levels may have been.

Discard data were included in the calculation of catch numbers at age. All discards were raised as one métier using the same age length keys and sampling information as for the landed catches. In the absence of better sampling information on discards, this was considered the best approach.

6.2 Biological composition of the catch

6.2.1 Catches in numbers-at-age

For 2012 catch number-at-age were prepared for Irish, Danish and Scottish landings using the ALK in table 6.2.1.1. This general ALK was constructed based on 814 aged fish from Irish, Danish and Scottish caught samples. There were a number of data quality issues (see section 6.2.2) and unsampled métiers. Allocations were made according to table 6.2.1.2. Only Irish collected samples were deemed reliable enough for length frequency and length weight analyses. In total 68 Irish samples were collected and 8565 fish were measured for length frequency.

For 2011, catch number-at-age were prepared for Irish, Danish and Scottish landings using the ALKs in table 6.2.1.3. There were a number of unsampled métiers and allocations were made according to tables 6.2.1.2 and 6.2.1.4. In total 27 samples were collected (16 by Denmark and 11 by Ireland), 4 066 fish were measured for length frequency and 704 fish were aged for construction of the ALKs.

For years prior to 2011, a proxy catch-at-age matrix was constructed using the ALK from a combination of fisheries-independent and dependent data (Table 6.2.1.5). For the years previous to 2007, this proxy ALK was applied to total discarded catches, also. Length-frequencies of commercial catches were available from 2007 onwards. Ageing was based on the method that has been validated for ages 0-7 by Hüssy *et al*. (2012a; 2012b). These age samples were collected mainly during 2010. The age range is similar to the published growth information presented by White *et al*. (2011).

ALKs were applied to commercial length-frequency data available for the years 2007-2012 to produce a proxy catch numbers-at-age (Figure 6.2.1.1 and Table 6.2.1.6). It can be seen that many older fish are still present in catches, though there appears to be a reduction of older ages since 2007. The modal age from 2007-2011 was 6 and in 2012 was 7. Other dominant age classes ranged from 4 to 8. It should be noted that in WGWIDE 2011 and 2012 the +group for boarfish was 20+. This was reduced to 15+ in WGWIDE 2013 due to potential inaccuracy of the age readings of older fish.

6.2.2 Quality of catch and biological data

Table 6.2.1.2 shows the number of samples available per year and allocations that were made to un-sampled métiers (Division*Quarter*Country). Length-frequencies of the international commercial landings by year are presented in Table 6.2.2.1.

Sampling in the early years of the fishery (2006-2009) was sparse as there was no dedicated sampling programme in place. The sampling programme was initiated in 2010 and good coverage of the landings has been achieved since then (Table 6.2.1.2). There is no DCF funded sampling of the fishery and all Irish sampling is industry funded. Irish sampling comprises only samples from Irish registered vessels. Samples are collected onboard directly from the fish pump during fishing operations and are frozen until returning to port. This ensures high quality samples. Each sample consists of approximately 6kg of boarfish. This equates to approximately 150 fish which given the limited size range of boarfish is sufficient for determining a representative length frequency. The established sampling target is one sample per 1 000 t of landings per ICES Division, which is also standard in other pelagic fisheries such as mackerel. All fish in each sample are measured to the 0.5cm below for length frequency. Following standard protocols 5 fish per 0.5cm length class are randomly selected from each sample for biological data collection i.e. otolith extraction, measurement to the 1mm below and sex and maturity determination. To date all Irish sample and data processing has been conducted by one person and the quality and consistency can be ensured.

In 2012 there were a number of quality issues with Danish collected samples. Danish sampling included 18 samples collected from Danish registered vessels, 26 samples from Irish registered vessels, 3 from British registered vessels and 4 from unidentified sources. The primary issue, which also occurred previously in 2011 with Danish samples, was the measuring of a substantial proportion of samples to 1.0cm instead of the established protocol of 0.5cm. Of the 18 samples collected from Danish registered vessels 6 were measured to the 1.0cm and 12 to the 0.5cm. Of the 26 samples collected from Irish registered vessels 11 were measured to the 1.0cm and 15 to the 0.5cm. All 3 samples collected from British registered vessels were measured to the 0.5cm, as were the 4 samples from unidentified sources. It is unclear why the Danish sampling programme sampled more foreign vessel landings than landings from Danish vessels. The majority of boarfish landings by Danish, Irish and Scottish vessels have been made into Danish ports in recent years however a comprehensive Irish vessel sampling programme is already established therefore samples collected from Irish vessels in Danish ports were considered to be duplicate samples. Further scrutiny of the 12 Danish samples from Danish vessels (measured to 0.5cm below) identified additional issues and errors with recorded catch dates and ICES Divisions and also with the raised catch numbers supplied when compared to raw data. Due to these issues it was deemed that Irish collected length frequencies were more reliable for constructing CNAA. A mixture of samples collected from Danish, Irish and Scottish vessels were aged and used to construct the general ALK. The 2012 age reading was conducted by the same reader who constructed the 2011 and 2010 ALKs, thus ensuring consistency in age reading.

It should be noted that in total 1267 boarfish were aged however 453 aged fish had been measured to the 1.0cm and were not included in the ALK as the 1.0cm length classification is not accurate enough for this species. The collection and processing of duplicate, incorrectly labelled and incorrectly measured samples represents a significant waste of time and efforts should be made to follow established protocols. Further efforts should also be made to coordinate sampling between countries to prevent duplicate sampling.

There is no sampling programme in place for Scottish catches. An error was identified with the Scottish landing data supplied. Landings were reported from ICES Divisions IVb (838 t) and IVc (907t) however boarfish are known to only occur sporadically in these Divisions. According to North Sea IBTS data less than 100 individual boarfish have been recorded in ICES Subarea IV in the past 16 years (Figure 6.1). These landings were queried with the vessels that reported them and it was revealed to be a simple error. They were reassigned to ICES Divisions VIIb and VIIc as these were the most likely source of the catches.

6.3 Fishery Independent Information

6.3.1 Acoustic Surveys

In July 2011, the Boarfish Acoustic Survey (BFAS) series was initiated. The 2011 survey was conducted by Marine Institute scientists aboard the Irish pelagic RSW vessel FV “Felucca’’ with a towed body system with a calibrated 38 kHz split beam transducer (O’Donnell *et al.*, 2012a). The survey was designed to extend the Malin Shelf Herring Acoustic Survey (MSHAS) conducted aboard the RV “Celtic Explorer” to the south, which increased the range of continuous coverage from approximately 58.5°N to 47.5°N (Figure 6.3.1.1). The 2011 BFAS operated on a 24 hour basis as it was an exploratory survey and the distribution and behaviour of boarfish during this time of year were unknown prior to the survey. The combined surveys resulted in a continuous coverage over 33 days, 90 000 nmi^2 and transect coverage over 4 500 nmi. 24 trawls were sampled and lengths, weights, maturity data and otoliths of boarfish were collected.

In July 2012 the BFAS series was continued, with the survey being conducted aboard the Irish pelagic RSW vessel FV ''Father McKee'' and funded by an Irish quota allocation of 1,400 tonnes (O'Donnell *et al.*, 2012b). The survey was again designed to extend the MSHAS conducted aboard the RV "Celtic Explorer" to the south as in 2011. The same equipment was used as during the 2011 survey and the survey track was broadly similar (Figure 6.3.1.1). In 2012 the survey methodology was refined by switching to daylight only (04:00-00:00) surveying. This change is protocol was a result of the observation during the 2011 BFAS that boarfish shoals were observed to break up during the night (00:00-04:00) and could not be acoustically detected or quantified. As a result it is likely that the 2011 survey is more of an underestimate of the biomass available at the time than the 2012 survey. It is considered that the daylight only sampling protocol has increased the precision of the survey estimate and should be maintained in the future.

In July 2013 the BFAS series was continued, with the survey being conducted again aboard the FV ''Felucca'' (O'Donnell *et al.*, 2013). The 2013 survey was funded by a general levy on all vessels participating in the boarfish fishery. The analysis of the data was co funded by the Marine Institute, United Fish Industries Ltd. and the Killybegs Fishermens' Organisation Ltd. The survey was again designed to extend the MSHAS conducted aboard the RV "Celtic Explorer" to the south as in 2011and 2012. The 2013 survey used the same equipment and followed the same protocol as the 2012 survey and the survey track was broadly similar (Figure 6.3.1.1). In total 4,295nmi (nautical miles) of cruise track was undertaken by both vessels over 53 transects relating to a total area coverage of 57,020nmi^2. Transect spacing was set at 15nmi for the *Felucca* and 15 and 7.5nmi for the *Explorer* component. Coverage extended in coastal areas from the c.50m contour to the shelf slope (250m). The survey was carried out from 04:00–00:00 each day.

As no species-specific target strength (TS) previously existed for boarfish, an industry funded project was conducted to model boarfish TS. Samples were collected during the 2011 survey and MRI scans were taken of the swim bladders from the observed size range of boarfish. 3D swimbladder dimensions of each fish sample were used as input to a KRM model. An estimated TS-L relationship of -65.98dB was derived based on model calculations. This TS was used in 2012 to produce biomass estimates for the 2012 and 2011 survey. In 2013 this TS was reviewed and revised to -66.2dB (Fässler *et al.*, 2013; O'Donnell, 2013). This new TS (-66.2dB) was applied to the 2013 survey data and retrospectively to the 2012 and 2011 BFAS survey data for use in the boarfish assessment.

The external reviewers recommended that the acoustic survey be extended to deeper waters to seek additional aggregations of boarfish. It should be noted that the current survey design does already provide for extension of transects offshore (west) if boarfish aggregations occur at the end of the transects. See section 6.6.1 for further discussion of the theory of offshore deep-water aggregations of boarfish.

6.3.2 International bottom trawl survey (IBTS)

The western IBTS data and CEFAS English Celtic Sea Groundfish Survey were investigated for their utility as abundance indices. An index of abundance was constructed from the following surveys:

EVHOE, French Celtic Sea and Biscay Survey, (Q4) 1997 to 2012

IGFS, Irish Groundfish Survey, (Q4) 2003 to 2012

WCSGFS, West of Scotland, (Q1 and Q4) 1986 to 2012 (no Q4 survey in 2010)

SPPGFS, Spanish Porcupine Bank Survey, (Q3) 2001 to 2012

SPNGFS, Spanish North Coast Survey, (Q3/Q4) 1991 to 2012

ECSGFS, CEFAS English Celtic Sea Groundfish Survey, (Q4) 1982 to 2003

From the IBTS data CPUE was computed as the number of boarfish per 30 minute haul. The abundance of boarfish per year per ICES Rectangle (used for visualisation only) was then calculated by summing the boarfish in a given rectangle and dividing by the total number of hauls in that rectangle. Length frequencies are presented in Table 6.3.2.2 for each survey. The spatial extent of each constituent survey of the IBTS is shown in Figures 6.3.2.1, 6.3.2.2a and 6.3.2.2b. These surveys cover the majority of the observed range of boarfish in the ICES Area (Figure 6.1). Figure 6.3.2.1 also includes the spatial range of the Portuguese Groundfish Survey (1990-2011), however this survey is outside the current EC TAC area and was not included in the index of abundance in 2013.

Anecdotal evidence from the fisheries indicates that from September to March boarfish are found on the shelf in dense shoals often in close proximity to the bottom. These shoals are particularly abundant around the banks in ICES Division VIIj in the Celtic Sea. Therefore boarfish are likely effectively sampled by the demersal gear of the IBTS despite being a pelagic species. However the shoaling nature of the species results in occasional large hauls.

The IBTS appears to give a relative index of abundance, with good resolution between periods of high and low abundance. The main centres of abundance in the survey (Figure 6.3.2.3) correspond to the main fishing grounds (Figure 6.2). Figure 6.3.2.4 shows the signal in abundance, increasing in the 1990s, declining again in the early 2000s, before increasing again. These trends have been reported by (Farina *et al.*, 1997; Pinnegar *et al.*, 2002; Blanchard and Vandermeirsch, 2005). These authors used IBTS and other trawl survey data to show the increased abundance of the species in this area.

The preliminary results of a GAM modelling project of the IBTS data up to 2011, including the Portuguese data, are presented to illustrate the temporal and spatial distribution of boarfish in the ICES Area. A GAM based on the probability of occurrence of boarfish in a surveyed area was developed based on presence absence data from over 13,000 individual fishing hauls in 7 groundfish surveys over a 30 year period (Figures 6.3.2.2a, 6.3.2.2b, 6.3.2.5a and 6.3.2.5b). The GAM models clearly illustrate that boarfish are distributed on the shelf and have a wide area of distribution. In recent years (2003 onwards) there has been an increase in the northerly distribution of boarfish. The depth distribution profile of boarfish within these hauls was also calculated, which shows that boarfish have a depth distribution preference of approximately 100-300m and the probability of occurrence in deeper water decreases sharply (Figure 6.3.2.6). The proportion of each region over which boarfish were distributed per year was also investigated and shows an increasing trend over time (Figure 6.3.2.7). This indicates that the area of spread of boarfish within the surveyed area has increased during the period.

For subsequent surplus production modelling, biomass indices were extracted from each of the IBTS surveys using a delta-lognormal model (Stefánsson, 1996). Many of the surveys exhibited a large proportion of zero tows (Figure 6.3.2.8) with occasionally very large tows, hence the decision to explicitly model the probability of a non-zero tow and the mean of the positive tows. A delta-lognormal fit comprises fitting two generalized linear models (GLMs). The first model (binomial GLM) is used to obtain the proportion of non-zero tows and is fit to the data coded as 1 or 0 if the tow contained a positive or zero CPUE, respectively. The second model is fit to the positive only CPUE data using a lognormal GLM. Both GLMs were fit using ICES rectangle and year as explanatory factor variables. Where the number of tows per rectangle was less than 5 over the entire series, they are grouped into an "others" rectangle. An index per rectangle and year is constructed, according to Stefánsson (1996), by the product of the estimated probability of a positive tow times the mean of the positive tows. The station indices are aggregated by taking estimated average across all rectangles within a year. To propagate the uncertainty, all survey index analyses were conducted in a Bayesian framework using MCMC sampling in WinBUGS (Spiegelhalter *et al.*, 2004).

6.4 Mean weights-at-age, maturity-at-age and natural mortality

Mean weight-at-age was obtained from the ageing studies of Hüssy *et al.* (2012b). These mean weights are presented in the text table below. The variation in weight-at-age is due to small sample size and seasonal variation in weight and maturity stage.

Age	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
MW g	0.84	6.65	14.65	19.49	23.71	26.75	33.29	37.73	40.03	47.11	50.24	51.16	62.75	56.44	62.25
Age	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**
MW g	68.86	50.52	86.69	77.94	64.56	63.52	75.02	86.05	71.01	76.97	84.42	79.38	-	67.60	52.77

Maturity-at-age was obtained from the ageing studies of Hüssy *et al.* (2012a; 2012b) and the reproductive study by Farrell *et al.* (2012).

Age	0	1	2	3	4	5	6+
Prop mature	0	0	0.07	0.25	0.81	0.97	1

Natural mortality (M) was estimated over the life span of the stock using the method described by King (1995). This method assumes that M is the mortality that will reduce a population to 1% of its initial size over the lifespan of the stock. Based on a maximum age of 31, M is calculated as follows:

$$M = \quad -\ln(0.01) / 31$$

Following this procedure M = 0.16 year^{-1}. M=0.16 is considered a good estimate of natural mortality over the life span of this boarfish stock, as it is similar to the total mortality estimate from 2007, (Z= 0.19, see Section 6.6.3). Given that catches in 2007 were relatively low, this estimate of total mortality might be considered a good estimate of natural mortality, assuming negligible fishing mortality in previous years.

Similarly, total mortality was estimated from age-structured IBTS data from 2003 to - 2006 (years from which data was available for all areas). The total mortality may be considered a good estimate of natural mortality as fishing mortality was assumed to be negligible during this period. Total mortality ranged from 0.09 – 0.2 with a mean of 0.16.

The special review of Chapter 6, in 2012, questioned the validity of a single estimate of M across the entire age range. If an age based assessment is possible in the future, age specific estimates of natural mortality are required. However, the current estimate of M, which covers the whole age range, is considered appropriate in the context of the current situation where age data are used as an indicator approach, rather than as a full assessment method. Given that Z and F are also calculated over the entire (fully selected) range (Section 6.6.3) a single value of M is considered appropriate.

6.5 Recruitment

The youngest consistent age in the fishery is 1, but full recruitment occurred at age 6 in all but 2012. The IBTS data were explored as indices of abundance of 1 year olds, and 1-5 year olds as a composite recruitment index (Figures 6.5.1 & 6.5.2). The EVHOE and SPNGFS surveys provide the best indices of recruitment as this is where the juveniles appear to be most abundant (Table 6.3.2.2). It appears that recruitment was high in the late 1990s but declined to a low in 2003, before increasing again. However, this apparent dip in recruitment was not observed in the commercial catch-at-age data (Figure 6.2.1.1). In 2011 there appeared to be another dip in recruitment. Recruitment appeared to increase in 2012.

6.6 Assessment

In 2012, a new stock assessment method was tested. In 2013 this method was further developed following the recommendations of the reviewers in 2012. Different applications of a Bayesian biomass dynamic model were run incorporating combinations of catch data, abundance data from the Groundfish surveys and the two estimates of biomass and associated uncertainty from the acoustic surveys in 2012 and 2013.

6.6.1 Historical literature sources

In the Northeast Atlantic region it is suggested that boarfish have historically undergone fluctuations in abundance. It should be noted that these apparent fluctuations in abundance occurred during periods when fisheries and fishery independent sampling were less widespread that the present day. The primary distribution areas of boarfish, on the Celtic Sea shelf in winter and along the shelf edge in summer, were rarely if ever sampled during this time. Therefore, the observations of peaks in abundance are only related to inshore areas. There is no evidence that boarfish were not also abundant in offshore waters throughout these periods. A literature review of historical sources suggests increases in abundance in the following periods:

1840s to 1880s

1950s

Mid 1980s to 1990s

From the 1840s to 1880s large abundances were periodically observed in the western English Channel (Day, 1880-1884; Couch, 1844; Cunningham, 1888). Gatcombe, writing in 1879, stated that they had become an extreme nuisance in trawl fisheries. In the early 1900s boarfish were noted for their sporadic occurrence in the English Channel and were scarce or absent for many years in the area around Plymouth where they had previously been abundant (Cooper, 1952). In the mid 1900s there was another apparent increase in abundance in the English Channel, which Cooper (1952) hypothesised was caused by a 'submarine eagre' that swept shoals of boarfish from submarine canyons in the southern edge of the Celtic Sea onto the continental shelf. There was no sound basis for this untested hypothesis and it is at odds with more reliable survey and fisheries data which indicates boarfish are a shelf species, which migrate to the shelf edge for spawning (see below).

Increases in abundance were observed in the Bay of Biscay, Galician continental shelf waters and the Celtic Sea between the 1980s and 2000 (Farina et al., 1997; Pinnegar *et al.*, 2002; Blanchard and Vandermeirsch, 2005). Based on EVHOE data the relative abundance in the Bay of Biscay was reported to have increased from 0.3% in 1973 to

16% in 2000 resulting in boarfish becoming one of the dominant species in the fish community in this region (Blanchard and Vandermeirsch, 2005).

Based on the above information the external reviewers in 2012 noted the possibility that boarfish was a deep-water species that had undergone a shoreward range extension onto the shelf in the late 1980's. They suggested that this was consistent with the large proportion of older fish in the stock and stated "If the increased abundance during the early 1990s was due to increasing recruitment on the continental shelf, then it seems unlikely that so many old fish would be observed". On this basis the reviewers made two recommendations: one was to extend the acoustic survey tracks into deeper water off shelf waters. This is already part of the standard protocol of the acoustic survey and since 2011 all westward transects extend until no boarfish shoals have been recorded for 15 nm (O'Donnell *et al.*, 2013). No boarfish shoals have been detected off the shelf from 2011 to 2013 and anecdotal evidence from the fishing industry also suggests that boarfish is a shelf species and does not occur off the shelf. The second recommendation was to use an integrated analysis model capable of simultaneously examining the age composition data, the catch time series, and the survey index time series to compare the movement hypothesis to the increased recruitment on the shelf hypothesis. Whilst it would be an interesting exercise this second point is deemed unnecessary as there is no evidence for boarfish being a deep water off-shelf species. It is also unclear why the reviewers considered that the increasing abundance during the early 1990's could not be due to increased recruitment on the shelf as these fish would now be in the 20+ age group and thus increased recruitment on the shelf could be the source of these fish.

Preliminary GAM modelling of the IBTS data also lends supports to the fact that boarfish are a shelf species (see section 6.6.2). There is no evidence of a spread of boarfish from oceanic waters onto the shelf. Furthermore the GAM models highlight where the theories such as this likely arose. The periodic increases in abundance in the western English Channel may simply have been an incursion of boarfish from shelf waters. Such incursions are evident from the GAM model in 1999 and 2002 (Figure 6.3.2.5b). The reasons for these incursions are unknown but may be related to annual hydrographic conditions. They do not occur in all years and as such likely result in a perceived local increase in abundance.

6.6.2 IBTS Data

The common ALK (Table 6.2.1.5) was applied to the number-at-length data. The length-frequency is presented in Table 6.3.2.2 and the age-structured index in Table 6.6.2.1 and Figure 6.6.2.1. A cohort effect can be seen with those cohorts from the early 2000s appearing weak. This coincides with a decline in overall abundance in the early 2000s. From the mid 2000s onwards recruitment improved as observed in the abundance of 1-5 year olds in the EVHOE and Spanish northern shelf surveys (see section 6.5 and Figures 6.5.1 & 6.5.2). It should be noted however that the IBTS data is measured to the 1.0cm not the 0.5cm. Therefore application of the common ALK to this data must be viewed with caution.

Some of the IBTS CPUE indices displayed marked variability with a large proportion of zero tows and occasionally very large tows (e.g., West of Scotland survey, Figure 6.3.2.8). More southern surveys, displayed a consistently higher proportion of positive tows (Figure 6.3.2.8). The variability of the data is reflected in the estimated mean CPUE indices (Figure 6.6.2.2). The West of Scotland survey index has been increasing since 2000 but is highly uncertain, whereas the estimate indices from the other series are typically less variable (Figure 6.6.2.2). The Spanish North Coast, EVHOE, and

Irish Groundfish surveys display broadly consistent trend in periods of overlap. The Spanish Porcupine Bank Survey fluctuates with a peak in 2005, a decrease and a recent increase in the years 2009-2011. The CEFAS English Celtic Sea Groundfish Survey displays a steady increase from the mid-1980s to 2002 with a large but somewhat uncertain estimate in 2003 (Figures 6.6.2.2 and 6.6.2.3). The spatial extent of each survey is shown in Figures 6.3.2.1 as per reviewers' comments (2012).

Diagnostics from the positive component of the delta-lognormal fits indicate relatively good agreement with a normal distribution on the natural logarithmic scale (Figure 6.6.2.4). There is indication of longer tails in some of the surveys (e.g., WCSGFS, EVHOSE, SPNGFS).

Pair-wise correlation between the annual mean survey indices varied. The IGFS, EVHOE and SPNGFS displayed positive correlation (Figure 6.6.2.5). The WCSGFS also displayed positive correlation with the IGFS and EVHOE surveys but a weakly negative correlation with the SPNGFS survey. The SPPGFS displayed no of flat correlation with the IGFS, EVHOE, SPNGFS (Figure 6.6.2.5). Weighting the correlations by the sum of the pair-wise variances, resulted in a largely similar correlation structure, though the WCSGFS was less correlated with the IGFS and EVHOE surveys and stronger correlated with the ECSGFS (Figure 6.6.2.6). Note that though some surveys displayed weak or no correlation, we did not a-priori exclude any surveys from the assessment runs. We do, however, conduct sensitivity tests to the exclusion of certain surveys as explained in the section 6.6.5.

6.6.3 Pseudo-cohort Analysis

Pseudo-cohort analysis is a procedure where mortality is calculated by means of catch curves derived from catch-at-age from a single year. This is in contrast to cohort analysis, which is the basis of VPA-type assessments. In cohort analysis, mortality is calculated across the ages of a year class, not within a single year. Because only six years of sampling data were available and owing to the large age range currently in the catches a cohort analysis would only yield information for a very limited age and year range. Therefore, pseudo-cohort analysis was performed.

Pseudo-cohort Z estimates increased with the rapid expansion of the fishery before decreasing significantly in 2011 due to the introduction of the first boarfish TAC (Table 6.6.3.1). By subtracting M (=0.16), an estimate of F was obtained for each year, over ages 6-14.

It can be seen from the text table below that Z ≈ M in 2007, the initial year of the expanded fishery, while F is negligible. F in 2010 has increased to an estimated 0.34. A positive correlation ($r^2 = 0.61$) was found between catch and F.

Year	Z	F (Z-M)	Catch
2007	0.19	0.03	21576
2008	0.35	0.19	34751
2009	0.35	0.19	90370
2010	0.34	0.18	144047
2011	0.28	0.12	37096
2012	0.31	0.15	87355

6.6.4 Biomass estimates from acoustic surveys

The revised modelled TS of -66.2dB (Fässler *et al.*, 2013; O'Donnell, 2013) was applied to the 2011, 2012 and 2013 BFAS data to produce new abundance estimates (Table

6.6.4.1). This table includes the CV for each estimate, as requested by the reviewers in 2012. Over the three years of the survey, biomass has been estimated in the range 439 897 t to 863 446 t. The 2011 survey is not directly comparable with the others, because data collection was both during day and night (24hrs). The 2013 survey biomass estimate is lower than that in 2012. The precision on the estimates has been good, with coefficients of variation in the range 10.7 to 16.7.

The large change in biomass observed between the 2013 and 2012 surveys (Table 6.6.4.1) cannot be easily explained and is no doubt the result of multiple factors (O'Donnell *et al.*, 2013). Expected inter-annual variation between successive acoustic estimates is in part responsible. However, factors outside survey effects should also be considered including hydrographic conditions and prey availability. As boarfish continue to feed during spawning the availability of prey will also determine spatial distribution of schools locally and clusters of schools at larger scales. If conditions for spawning are not optimum then the prey availability will drive distribution. As the survey covered the same area using the same survey design and good trawl sampling was achieved it is methodologically a replicate of that performed in 2012. However, factors outside of the survey have no doubt influenced the distribution of the stock both in the large scale (how it was distributed over the greater survey area) and at the smaller scale (in terms of schooling behaviour). The latter being directly related to how available boarfish were to the acoustic recording equipment. As no bottom trawl was available during the survey it was not possible to target the seabed within the acoustic dead zone (ADZ) for presence/absence of boarfish. Unquantified sonar observations and off track investigations indicated that echosounder observations were indeed representative of aggregations present in the wider area. This raises the possibility that boarfish could have also been distributed within the ADZ and out of the range of echosounder and midwater trawl sampling.

In 2013 thirty three hauls were carried out during the survey, 19 of which contained boarfish. A total of 1,074 boarfish echotraces were identified during the survey. Of this 98% were categorised as 'definitely' boarfish, 1.6% as 'probably' and 0.3% 'boarfish in a mixture' (see text table below for explanation of categories). Following standard acoustic survey protocols the Total Stock Biomass estimate includes the *Definitely*, *Probably* and *Mixture* categories but excludes the *Possibly* category.

Category	Definition
Definite	"Definitely" echotraces were identified on the basis of captures of boarfish from the fishing trawls which were sampled directly. Based on the directly sampled schools echotraces were also characterised as definitely boarfish which appeared very similar on the echogram i.e. large marks which showed as very high intensity (red), located high in the water column(day) and as strong circular schools.
Probably	"Probably" was attributed to smaller echotraces that had not been fished but which had similar characteristics to "definite" boarfish traces.
Mixture	"Mixture" was attributed to NASC values arising from all fish traces in which boarfish were contained, based on the presence of a proportion of boarfish in the catch or within the nearest trawl haul. Boarfish were often taken during trawling in mixed species layers during the hours of darkness.
Possibly	"Possibly" was attributed to small echotraces outside areas where fishing was carried out, but which had the characteristics of definite boarfish traces.

A full breakdown of school categorisation, abundance and biomass by ICES statistical rectangle is available in O'Donnell *et al.* (2013). The southern area contained the largest proportion of stock biomass (64%). The second most abundant area was the western area where 21% of biomass was recorded. The northern area and Porcupine Bank contributed 3% and 12% respectively. The proportion of the stock biomass within each area is similar to that observed in 2011-2012. The total number of echotraces detected in 2013 was comparable to 2012 (6% lower), however, acoustic density of these echotraces was much reduced. The single largest boarfish NASC in 2013 was 75% less than the largest observed in the previous year. Echotrace identification was considered accurate with over 98% of the total biomass attributed to the "definite" category. The ability to scrutinise echotraces to this degree was achieved through comprehensive trawl sampling. The percentage contribution of estimated biomass across the four survey areas in 2013 was comparable to 2012, with the south and west ranking highest followed by the Porcupine Bank and northern area respectively. However, acoustic density was much lower in 2013 as was individual school size and clustered spawning aggregations. Along track sonar observations made during the survey support echosounder observations in that school density was lower and more scattered.

In 2012 a total of 1,168 boarfish schools were identified during the survey. Of this 82 % were categorised as 'definitely' boarfish, 14% as 'probably', 4% 'boarfish in a mixture' and 0.6% as 'possibly'. The total number of schools detected in 2012 was 17% higher than in 2011 whereas school allocation to the definite category remained comparable with 80% (+/-1%) in both years. The main difference between years related to school size (NASC value) with 3 individual schools observed in 2012 of higher NASC value than the largest school recorded in 2011. The largest of which was over 52% greater than the maximum recorded in 2011. The increased number and size of schools observed in 2012 is reflected in the over 47% increase in acoustic-estimated biomass between years.

Three areas of high core abundance were noted during the 2012 survey. The first, along the west coast of Ireland (52°-54°N) where a large number of high density mono-specific schools and numerous small high density schools were found. This area contributed the most to the overall TSB and contained 2 of the highest biomass strata of the survey. Boarfish in this area were predominantly distributed in water depths between 70-140m and schools were often located higher in the water column (c.40m from surface) than in areas further south. Moving south into the Celtic Sea, the second highest density core area was located between 49°'30N and 47° 30'N (southern area). This area also contained numerous high density mono-specific schools and as with the western area is consistent with the 2011 survey as an area of high abundance during spawning.

In 2011 boarfish schools along the shelf break in the southern region (48°-49°'30N) were located close to/on the bottom and often mixed with horse mackerel in high density homogeneous layers. This area is a known hot spot for horse mackerel in the commercial fishery. In these high abundance areas trawling close to the bottom was not always possible due to the complex bathymetry and possibility of gear damage. In such instances this would have left a portion of the stock unaccounted for. In 2012 boarfish schools in this area were observed to occupy a position slightly off the bottom, allowing for effective trawl sampling and accurate categorisation. The switch to daylight surveying has also no doubt led to an increase in school detection and as a result survey abundance, more so than could be attributed to year effects alone.

It should be noted that the survey did not contain the stock fully, given that concentrations of boarfish are likely to be found southward of the survey area as evidenced by both IBTS data and information from the PELACUS survey on the northern Spanish Shelf (Carrera *et al.*, 2013). However, the results suggest that the stock is of large size and is widely distributed.

6.6.5 Biomass dynamic model

Exploratory assessment 2012 and reviewers' comments

In 2012, an exploratory biomass dynamic model was developed. This was a Bayesian state space surplus production model (Meyer and Millar, 1999), incorporating the catch data, IBTS and acoustic biomass data. This assessment was peer-reviewed by two independent experts on behalf of ICES. In 2013, a new assessment is provided, that is based on last year's work and takes into account the reviewers' comments.

The reviewers suggested that an age based model would be most appropriate. An age based model, however, is not attainable in the short term because:

- Insufficient age samples are available per year to derive representative CNAA.
- The age range of the species is wide and the year range of the fishery is narrow, making it impossible to populate the age-matrices of any such model in the short term.

The impediments to having an age based assessment can be overcome with time. The reviewers recommend the development of an age-based assessment in a 3-year timeframe. A cost-benefit analysis is required on whether to pursue an age based approach. At present there are insufficient resources for a full ageing programme. The reviewers suggested that more samples with fewer fish per sample and to refine the age length relationship for older fish. Perhaps the most expedient approach is to collect a large amount of samples, but only age a sub-set of these to maintain the indicator pseudo-cohort F estimates. If better resources are considered to be warranted, then the back-log of samples could be aged to produce CNAA over several years.

Given the problems with an age-based assessment, it was necessary to develop the biomass dynamic model further, whilst paying attention to the reviews conducted in 2012. The main points of the reviews on the biomass dynamic model are presented in the text table below, along with notes on how they were addressed.

Reviewer comment	How addressed
Provide indication of steepness of stock recruitment relationship	The model does not provide modelled recruitment, so this is not relevant to current model specification.
Better description of weighting of individual surveys	Surveys are weighted based on the survey index variability. A highly uncertain survey is therefore down-weighted within the assessment as detailed below. Apart from the index uncertainties, no a-priori weights are given to the indices although sensitivities to the exclusion of certain surveys were conducted and described below.
Clarification of rationale for model(run) selection	We now include a full clarification on final run selection.

Provide sensityivity analysis of prior assumptions	We include a sensitivity analysis to prior assumptions based on a "low resilience" assumption of WKLIFE (ICES, 2012) based on the maximum age for the species.
Need to describe process error to observation error	The process error and observation errors are described in full below.
Better description of Monte Carlo Markov Chain simulations	We not include traceplots of MCMC chains for the all runs to illustrate convergence accompanied by the Rhat statistic (ratio of between-chain to within-chain variance) with Rhat =1 indicating perfect convergence and Rhat < 1.1 indicative of acceptable convergence (Kéry, 2010). We also present autocorrelation functions of the final run to indicate MCMC sample independence.
Better description of catch used as inputs, including discards	Discards are described in Section 6.1.6.
Sensitivity analysis required on model results to assumptions on error variances	Measurement error variances come directly from the survey index analyses. The estimated process error variance is very strongly updated from a gamma prior on the precision so we don't think a sensitivity analysis is warranted for the error variances.
Show correlation among abundance indices	Now presented in Figures 6.6.2.5 and 6.6.2.6.
Include sensitivity analysis for including indices with zero or negative correlations with other indices	Again, the survey indices are internally weighted by their measurement error uncertainty and we do not a priori exclude series. Our sensitivity analyses remove the WCSGFS and ECGFS. The ECGFS survey displays negative correlation with the EVHOE and SPNGFS.

A Bayesian state space surplus production model (Meyer and Millar, 1999) was fit using the catch data, delta-lognormal estimated IBTS survey indices, and the acoustic survey estimates. The biomass dynamics are given by a difference form of a Schaefer biomass dynamic model:

$$B_t = B_{t-1} + rB_{t-1}\left(1 - \frac{B_{t-1}}{K}\right) - C_{t-1}$$

where B_t is the biomass at time t, r is the intrinsic rate of population growth, K is the carrying capacity, and C_t is the catch, assumed known exactly. To assist the estimation the biomass is scaled by the carrying capacity, denoting the scaled biomass $P_t = B_t/K$. Lognormal error structure is assumed giving the scaled biomass dynamics (process) model:

$$P_t = \left(P_{t-1} + rP_{t-1}(1 - P_{t-1}) - \frac{C_{t-1}}{K}\right)e^{u_t}$$

where the logarithm of process deviations are assumed normal $u_t \sim N(0, \sigma_u^2)$; σ_u^2 is the process error variance.

The starting year biomass is given by aK , where a is the proportion of the carrying capacity in the first year. The biomass dynamics process is related to the observations on the indices through the measurement error equation:

$$I_{j,t} = q_j P_t K e^{\varepsilon_{j,t}}$$

where $I_{j,t}$ is the value of abundance index j in year t, q_j is survey-specific catchability, $B_t = P_t K$, and the measurement errors are assumed lognormally distributed with ; $\varepsilon_t \sim N(0, \sigma^2_{\varepsilon,j,t})$; where $\sigma^2_{\varepsilon,j,t}$ is the index-specific measurement error variance $\mathrm{Var}(I_{j,t})$ obtained from the delta-lognormal survey fits. That is, the variance of the mean annual estimate per survey is inputted directly from the delta-lognormal fits (Figure 6.6.2.2) as opposed to estimating a measurement error within the assessment. The measurement error is obtained from:

$$\sigma^2_{\varepsilon,j,t} = \ln\left(1 + \frac{\mathrm{Var}(I_{j,t})}{(I_{j,t})^2}\right)$$

For the acoustic survey, the CV of the survey was transformed into a lognormal variance via

$$\sigma^2_{\varepsilon,acoustic,t} = \ln\left(CV^2_{acoustic,t} + 1\right).$$

Prior assumptions on the parameter distributions were:

- Intrinsic rate of population growth: $r \sim U(0.001,2)$
- Natural logarithm of the carrying capacity ln $K \sim U$(ln max(C), ln 10xsum C)=U(ln 144,047t, ln 4,450,407t)
- Proportion of carrying capacity in first year of assessment: $a \sim U(0.001, 1.0)$
- Natural logarithm of the survey-specific catchabilities ln $q_i \sim U(-16,0)$ (for IBTS only). Acoustic survey is discussed below when separate runs are described.
- Process error precision $1/\sigma^2_u$ ~Gamma(0.001,0.001)

Eight initial runs were performed. The four base runs are explained in the table below:

Run	$q_{acoustic}$	$I_{acoustic,2012}$ (t)	$I_{acoustic,2013}$ (t)
1	Fixed at 1	Total (863,446)	Total (439,897)
2	Free (strong prior)	Total	Total
3	Fixed at 1	Definitely (708,019)	Definitely (431,571)
4	Free (strong prior)	Definitely	Definitely

$q_{acoustic}$ is the catchability of the acoustic survey, $I_{acoustic}$ is the acoustic index value used for the specified years.

Runs 1 and 3 assume that the acoustic survey surveys the entire stock and is an absolute index of abundance. Runs 2 and 4 assumes a strong prior ln $q_{acoustic}$ ~ N(1,1/4) (standard deviation of 1/4), which has 95% of the density between 0.5 and 2. Given the short acoustic series (2 years) it is not possible to estimate this parameter freely (using an uninformative prior) but assuming a strong prior removes the assumption of an absolute index from the acoustic survey and will be continually updated as data accrue.

Following concerns regarding the quality of the recording of boarfish from the early part of the ECSGFS survey and the fact that the WCSGFS survey is distant from the center of abundance and unlikely to provide an index for the complete stock, sensitivity runs were performed on Runs 1-4 that completely omitted the ECSGFS and WCSGFS surveys. These are referred to as runs 1.1, 2.1, 3.1, and 4.1 with the same settings as the corresponding runs 1 through 4 respectively with the omission of these two surveys.

Following plenary discussion of the sensitivity runs, it was decided that the final run be based on a run that includes all surveys with the omission of the first 5 years of the WCSGFS and first 9 years of the ECSGFS. The reasons for this decision was

- It is unclear whether boarfish were consistently recorded in the early part of the ECSGFS
- The WCSGFS is thought to be at the northern extreme of the distribution and may not be an appropriate index for the whole stock.
- The SPNGFS commences in 1991 such that running the assessment from 1991 onwards includes at least three surveys without relying solely on the ECSGFS and WCSGFS.
- Surveys are internally weighted such that highly uncertain values receive lower weight.

Run 2.2. is therefore the final run. The specifications are that for run 2 with the omission of the early parts of the WCSGFS and ECSGFS, as detailed above.

Run convergence

Parameters for runs 1-4, sensitivity runs 1.1, 2.1, 3.1, 4.1 and final run 2.2 converged with good mixing of the chains and Rhat values lower than 1.1 indicating convergence (Figures 6.6.5.1, 6.6.5.2 6.6.5.3). MCMC chain autocorrelation was also low indicating good sampling of the parameter posteriors (Figures 6.6.5.4 and 6.6.5.5).

Diagnostic plots for these runs are provided in Figures 6.6.5.6 and 6.6.5.7, showing residuals about the model fit. There is relatively little difference between any of the runs in the fitting of the trawl surveys, and a fairly balanced residual pattern is in evidence. In some cases outliers are apparent, for instance in the English survey in the final year (2003). However, these points are down-weighted according to the inverse of their variance and hence to not contribute much to the model fit. For this reason, no indices were removed from the analyses. The west of Scotland IBTS survey, located at the northern extreme of the stock distribution underestimates the stock in the early period (years) and overestimates it in the recent period from all fits. This could be indicative of stock expansion into this area at higher stock sizes and suggests that this index is not representative of the whole stock. Figures 6.6.5.8, 6.6.5.9 and 6.6.5.10 show the prior and posterior distributions of the parameters of the biomass dynamic model. The estimate of q in runs 2, 2.1, 4 and 4.1 is less than 1.0, leading to higher estimates of final stock biomass than the acoustic survey.

Trajectories of observed and expected indices are shown in Figures 6.6.5.11, 6.6.5.12 and 6.6.5.13, along with the stock size over time and a harvest ratio (total catch divided by estimated biomass). It can be seen that runs 2, 2.1, 2.2, 4 and 4.1 lead to larger stock sizes given the non-absolute assumption on the acoustic survey catchability. Parameter estimates from the four preliminary runs (1-4), four sensitivity runs (1.1, 2.1, 3.1, 4.1) and the final run (run 2.2) are summarized in Table 6.6.5.1. It can be seen that the precision of the estimates of stock size are higher (more certain) for the runs where q is set at 1.0 for the acoustic surveys (Runs 1, 3, 1.1, 3.1). As the acoustic survey does not span the entire range of the stock, assuming the catchability of the acoustic survey is likely incorrect, hence the decision to use a strong prior on the acoustic survey catchability. Consequently the group considers run 2.2 as the final run for the purposes of stock assessment and forecasting catch options for 2013.

6.6.6 State of the stock

The analyses including all series back to 1982 (runs 1-4) suggest that the stock has increased from low levels, to a high level in the early 1990s. The stock fluctuated at this high level, though increased again to reach a peak in abundance in 2010. Elevated fishing mortality, associated with the highest recorded catch, in that year, was observed. The fishing mortality declined again, in 2011, as catches became regulated by the precautionary TAC.

Catch data are available from 2001, the first year of commercial landings. Reasonably comprehensive discard data are available from 2003. Peak catches were recorded in 2010, when over 140 000 t were taken.

Fishing mortality, expressed as a harvest ratio (catch divided by total biomass) was first recorded in 2003. Before that time, it is to be expected that some discarding took place, and there were some commercial landings. However the mortality increased measurably from 2006, reaching a peak in 2009 and 2010, before declining again in 2011. F increased again in 2012, but is still below F_{msy}. The high catches in 2010 are associated with relatively low estimated F, suggesting that this is a large stock. The considerable catches in the past two years do not appear to have significantly truncated the size or age structure of the stock and 15+ group fish are still abundant (Figure 6.2.1.1).

From the final accepted run (2.2), biomass appears to have increased from lower levels in the early 1990s. By the mid-1990s the stock had grown and continued to fluctuate to 2009. Biomass increased to new levels in 2010, though it declined in 2011, slightly increased in 2012 and then decreased in 2013. It is still considerably higher than the estimated B_{msy} (Table 6.6.5.1). The uncertainty surrounding the estimates of biomass in the final year are high (Table 6.6.5.2), this reflects the uncertainty in the survey indices, and short exploitation history of the stock and the fact that we treat the acoustic survey as a relative biomass index. As more data accumulates from this survey, we expect that the prior will become increasingly updated, potentially less variable. Reflective of the uncertainty, short-term forecasts are presented with associated probabilities of crossing reference points for given levels of fishing mortality.

Estimates of recruitment are not available from the stock assessment. However, an independent index of recruitment is available from groundfish surveys (section 6.5). Observations from the survey recruitment of 1 year olds in 2011 were lower than in other recent years. In 2012 recruitment appeared to increase (Figures 6.5.1 and 6.5.2).

Overall, the perception remains of a large, widely distributed stock that is not being over exploited.

6.7 Short term projections

A short term forecast was performed by projecting run 2.2 forward by one year. However, as there is no recruitment estimate it is not possible to construct a traditional style catch forecast for management purposes. Instead, short term projections over a range of fishing mortality and catch options are provided on a risk based approach. An intermediate year catch constraint was applied (2013 TAC, 82 000 t + average discards of 6 448 t). The population is then projected forward within the assessment under a range of management objectives that included the yield at:

- F_{MSY}=0.23 based on *r*/2 from run 2.2 (Table 6.6.5.1)
- $F_{0.1}$=0.13 based on yield-per-recruit analysis
- F_{lim}=0.367 based on the F associated with a long-term biomass of *K*/5 (0.2 carrying capacity used for B_{lim})
- $F_{pa}=\exp(-1.645*CV(TSB_{2013}))*F_{lim} = \exp(-1.645*0.436)* 0.367 = 0.179$
- $C_{2014}=C_{2013}$
- $C_{2014}=0$ (zero catch option)
- $C_{2014}=1.2*C_{2013}$ (20% increase in catch)
- $C_{2014}=0.8*C_{2013}$ (20% decrease in catch)

A forward projection on the risk of the stock falling below B_{msy} ($B_{trigger}$), B_{lim} and fishing mortality exceeding F_{lim} are estimated. Catch options are presented in Table 6.7.1. Fishing mortality for the fixed catch projections is calculated as $-\ln(1-C_{2014}/TSB_{2014})$.

Given that mean total stock biomass in 2013 is greater than $B_{trigger}$ (Table 6.6.5.1), fishing at F_{msy} is consistent with the ICES MSY approach. For run 2.2 this results in a 2014 catch of 133 957 t. There is a high level of uncertainty associated with this F_{MSY}, which is reflected in a 25.3% probability of falling below $B_{trigger}$ in 2015. Fishing at F_{lim} elevates this probability to 34.6%, while fishing at F_{pa} decreases the probability to 21.6%. The probability of dropping below B_{lim} while fishing at F_{MSY} is considerably lower at 1.4% (Table 6.7.1). We note that the probability of dropping below $B_{trigger}$ at zero catch is 12% again reflecting the uncertainty of the biomass trajectory.

6.7.1 Yield Per Recruit

A yield per recruit analysis was conducted in 2011 (Minto *et al.*, WD 2011) and $F_{0.1}$ was estimated to be 0.13 whilst F_{max} was estimated in the range 0.23 to 0.33 (Figure 6.7.1.1). $F_{0.1}$ was considered to be well estimated (Figure 6.7.1.2). No new yield per recruit analyses were performed in 2012 or 2013.

6.8 Long term simulations

No long term simulations were conducted.

6.9 Precautionary and yield based reference points

6.9.1 Precautionary reference points

It does not appear that boarfish is an important prey species in the NE Atlantic (Section 6.12). ICES (1997) considered that precautionary F targets (F_{pa}) should be consistent with F<M for prey species. This approach would ensure that fishing does not out-compete natural predators for their prey. This would suggest that a good candi-

date precautionary F_{pa} can be defined as exp(-1.645*CV(TSB_{2013}))*F_{lim}=0.179. B_{lim} may be defined from the stock size estimates available from the stock assessment. It is proposed that B_{lim} be set at 0.2* *K*, (0.2 * 911 209 t = 182 241 t), based on the results of Run 2.2 (Table 6.6.5.1).

6.9.2 Yield based reference points

Yield per recruit analysis, following the method of Beverton and Holt (1957) found $F_{0.1}$ to be robustly estimated at 0.13 (ICES WGWIDE, 2011; Minto *et al.*, WD 2011).

An estimate of F_{msy} is available from the stock assessment as 0.23, which is in close agreement with the lower range of F_{max} from yield per recruit analyses (0.23 to 0.33; Minto *et al.*, WD 2011).

An estimate of B_{msy} is available from stock assessment Run 2.2 (455 605 t). This is proposed as a conservative basis for MSY $B_{trigger}$.

6.10 Quality of the Assessment

This is the first time that a full stock assessment has been conducted for this stock. A considerable amount of data has been collected and analysed. The stock assessment method made use of all available fisheries independent data, and available landings and discard data too. Age data have been collected and analysed, but the time series is too short to be useful for an age-based assessment of this long lived species.

The bottom trawl survey data are considered to be a good index of abundance given that boarfish aggregate on the bottom at this time of year. The trawl surveys record high abundances of the species, but with many zero hauls. The delta-log normal error structure used in the analyses is considered to be a good means of dealing with such data. The biomass dynamic model used in the stock assessment is based on the recent Benchmark of megrim in Sub-divisions IV and VI. The model was further developed by including acoustic survey biomass estimates. One drawback of the model is that it does not provide estimates of recruitment. However, an estimate of recruitment strength is available from the Spanish and French trawl surveys.

Boarfish cannot be considered a data poor stock, and the group considers that the stock assessment is a good indicator of stock status. However, in view of the new and developing nature of the fishery, uncertainty surrounding the final estimates, and considering that the biological information on the stock is constantly being updated, precaution is warranted, when considering catch options for 2014.

6.11 Management Considerations

The available data suggests that this is a large stock. Stock size in 2013 is estimated to be 653 668 t, though at this stage of the development of the assessment absolute estimates of stock size are uncertain. Trends in abundance over time indicate that the stock has increased from very low levels in the 1980s, to high levels in the 1990s. It declined somewhat in the early 2000s and recruitment weakened. Since the mid 2000s the stock has increased to 2010 and declined from 2012-2013.

Fishing mortality is estimated to have increased from a negligible rate in 2007 to a peak of 0.154 in 2010 and was 0.09 in 2012. This is lower than $F_{0.1}$ and M. The large reduction in catch, resulting from the 2011 TAC (75% decrease in landings from 2010) reduced F considerably.

Overall results of data explorations indicate a large, widely distributed stock that has recently increased in abundance and is not over exploited.

The management plan that has been proposed by the Pelagic RAC has not yet been evaluated by ICES. Therefore it is unlikely to form the basis of ICES advice for 2013. Instead, ICES advice is likely to be based on the MSY approach. However, in order to be faithful to the precautionary approach to new and developing fisheries, it seems prudent to only consider cautious expansion.

6.12 Ecosystem considerations

The ecological role and significance of boarfish in the NE Atlantic is largely unknown. However, in the south-east North Atlantic, in Portuguese waters, they are considered to have an important position in the marine food web (Lopes *et al.*, 2006). The diet has been investigated in the eastern Mediterranean, Portuguese waters and at Great Meteor Seamount and consists primarily of copepods, specifically *Calanus helgolandicus*, with some mysid shrimp and euphausiids (MacPherson, 1979; Fock *et al.*, 2002; Lopes *et al.*, 2006). This contrasted with the morphologically similar species, the slender snipefish, *Macroramphosus gracilis* and the longspine snipefish, *M. scolopax*, whose diet comprised *Temora* spp., copepods and mysid shrimps, respectively (Lopes *et al.*, 2006). Despite the obvious potential for these species to feed on fish eggs and larvae, there was no evidence to support this conclusion in Portuguese waters and they were not considered predators of commercial fishes and thus their increase in abundance was unlikely to affect recruitment of commercial fish species (Lopes *et al.*, 2006). If the NE Atlantic population of boarfish is sufficiently large then there exists the possibility of competition for food with other widely distributed planktivorous species.

Both seasonal and diurnal variations were observed in the diet of boarfish in all three regions. In the eastern Mediterranean and Portuguese waters, mysids become an important component of the diet in autumn, which correlates with their increased abundance in these regions at this time (MacPherson, 1979; Lopes *et al.*, 2006). Fock *et al.* (2002) found that boarfish at Great Meteor Seamount fed mainly on copepods and euphausiids diurnally and on decapods nocturnally, indicating habitat dependent resource utilisation.

Boarfish appear an unlikely target of predation given their array of strong dorsal and anal fin spines and covering of ctenoid scales. However, there is evidence to suggest that they may be an important component of some species' diets. Most studies have focused in the Azores and few have mentioned the NE Atlantic, probably due to the relatively low abundance in the region until recent years. In the Azores, boarfish was found to be one of the most important prey items for tope (*Galeorhinus galeus*), thornback ray (*Raja clavata*), conger eel (*Conger conger*), forkbeard (*Phycis phycis*), bigeye tuna (*Thunnus obesus*), yellowmouth barracuda (*Sphyraena viridensis*), swordfish (*Xiphias gladius*), blackspot seabream (*Pagellus bogaraveo),* axillary seabream (*Pagellus acarne*) and blacktail comber (*Serranus atricauda*) (Clarke *et al.*, 1995; Morato *et al.*, 1999; Morato *et al.*, 2000; Morato *et al.*, 2001; Barreiros *et al.*, 2002; Morato *et al.*, 2003; Arrizabalaga *et al.*, 2008). Many of these species also occur in the NE Atlantic shelf waters although it is unknown whether boarfish represent a significant component of the diet in this region.

In the NE Atlantic boarfish have not previously been recorded in the diets of tope or thornback ray (Holden and Tucker, 1974; Ellis *et al.*, 1996,). However, this does not prove that they are currently not a prey item. A study of conger eel diet in Irish waters from 1998-1999 failed to find boarfish in the diet (O'Sullivan *et al.*, 2004). However, in Portuguese waters a recent study has found boarfish to be the most numerous species in the diet of conger eels (Xavier *et al.*, 2010). It has been suggested that boarfish are an important component of the diet of hake (*Merluccius merluccius*), as they are sometimes caught together. However, a recent study of the diet of hake in the Celtic Sea and Bay of Biscay did not report any boarfish in the stomachs of hake caught during the 2001 EVHOE survey (Mahe *et al.*, 2007).

The conspicuous presence of boarfish in the diet of so many fish species in the Azores is perhaps more related to the lack of other available food sources than to the palatability of boarfish themselves. Given the large abundance in NE Atlantic shelf waters it is likely that they would have been recorded more frequently if they were a significant and important prey item.

Boarfish are also an important component of the diet a number of sea birds in the Azores, most notably the common tern (*Sterna hirundo*) and Cory's shearwater (*Calonectris diomedea*) (Granadeiro *et al*., 1998; Granadeiro *et al*., 2002). This is surprising given that in the Mediterranean discarded boarfish were rejected by seabirds whereas in the Azores they were actively preyed on (Oro and Ruiz, 1997). Cory's shearwaters are capable of diving up to 15 m whilst the common tern is a plunge-diver and may only reach 2-3 m. It is therefore surprising that boarfish are such a significant component of their diet given that it is generally considered a deeper water fish. In the Azores boarfish shoals are sometimes driven to the surface by horse mackerel and barracuda where they are also attacked by diving sea birds (J. Hart, CW Azores, pers. comm.). Anecdotal reports from the Irish fishery indicate that boarfish are rarely found in waters shallower than 40 m. This may suggest that they are outside the range of shearwaters and gannets, the latter having a mean diving depth of 19.7±7.5 m (Brierley and Fernandes, 2001). However, the upper depth range of boarfish is within maximum diving depth recorded for auks (50 m) as recorded by Barrett and Furness (1990). Given their frequency in the diets of marine and bird life in the Azores, boarfish appear to be an important component of the marine ecosystem in that region. There is currently insufficient evidence to draw similar conclusions in the NE Atlantic.

The length-frequency distribution of boarfish may be important to consider. IBTS data shows an increase in mean total length with latitude (Table 6.3.2.2) and perhaps the smaller boarfish in the southern regions are more easily preyed upon. Length data of boarfish from stomach contents studies of both fish and sea birds in the Azores indicate that the boarfish found are generally < 10 cm (Granadeiro *et al*., 1998; Granadeiro *et al*., 2002).

6.13 Changes in the environment

Studies are underway to investigate if the increase in abundance of boarfish in the 1990s and 2000s is related to changes in the environment. Blanchard and Vandermeirsch (2005) attributed the increase in abundance of boarfish in the EVHOE survey during this time to a concurrent increase in water temperature during the spawning season which may have enhanced recruitment.

The reproductive biology of the species goes some way to supporting and developing this theory. Evidence suggests that the boarfish is an asynchronous batch spawner with indeterminate fecundity (Farrell *et al*., 2012). Given suitable conditions (i.e. suitable temperature and abundant prey) boarfish are capable of spawning repeatedly over an extended period of time. In aquarium conditions, spawning has been observed daily for males and every 2-3 days for females over a period of nine consecutive months. Natural conditions are more variable and Farrell *et al.* (2012) indicated that spawning was restricted to the summer months with a peak in July. Spawning had ceased by September and remaining oocytes were resorbed at this time.

If conditions remain favourable for an extended period of time in a particular year then boarfish are likely to continue spawning possibly leading to enhanced recruitment. Analyses of IBTS length-frequency, temperature and plankton data are ongoing to investigate if the years of high and low recruitment can be related to environmental variables.

6.14 Proposed management plan

A management plan has been proposed by the Pelagic RAC. This plan is presented below.

The TAC setting rules 1.1-1.6 shall apply. Precedence is in decreasing order from Rule 1.1. These are shown in the table below. The decision year for TAC setting is the last year in the assessment, and not the TAC year.

Rule	Assessment	Uncertainty	Condition	Procedure
1.1.a	SSB and F	Low	SSB > $B_{trigger}$	F_{target}
1.1.b			SSB < $B_{trigger}$	SSB * (F_{target} / $B_{trigger}$)
1.2.a	SSB and F	Higher	SSB > $B_{trigger}$	F_{target}
1.2.b			SSB < $B_{trigger}$	SSB * (F_{target} / $B_{trigger}$) * G
1.3.a	F	Any	F < F_{target}	Reference TAC * G
1.3.b			F > $F_{target,}$	RTAC + (-RTAC / F_{lim}-F_{pa})*(F-F_{pa}) * G
1.4.a	U	Any	U > $U_{pa,}$ TAC =	Reference TAC * G
1.4.b			U < $U_{pa,}$ TAC =	U * (Reference TAC / U_{pa}) * G
1.5.	Survey biomass	Any	TAC y,q3,4 = TACy+1, q1 =	ASB * 1-exp-$^{F_{0.1}}$_ * G * 0.62 ASB * 1-exp-$^{F_{0.1}}$_ * G * 0.38
1.6	None		No information on stock status *and* no risk of recruitment impairment	TAC = 33,000 t (interim management plan TAC)

SSB = Spawning stock biomass, F = Fishing mortality in units per year, U = Fisheries independent abundance index, from IBTS survey, C = Commercial catch in tonnes, TSB = Total stock biomass in tonnes

Notwithstanding Paragraph 1, if in the opinion of ICES, the stock is at risk of recruitment impairment, a TAC shall be based on advice given by ICES, and at a lower level than provided for in Paragraph 1, rules 1.1 to 1.6.

Closed seasons, closed areas and moving on procedures shall apply to all directed boarfish fisheries as follows:

i A closed season shall operate from 15th March to the 31st August. This is because it is known that herring and mackerel are present in these areas and may be caught with boarfish.

ii A closed area shall be implemented inside the Irish 12 mile limit south of 52°30 from 12th February to 31st October, in order to prevent catches of Celtic Sea herring, known to form aggregations at these times.

iii If catches of other species covered by TAC, amount to more than 5% of the total catch by day by ICES statistical rectangle, then all fishing must cease in that rectangle for 5 consecutive days.

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Table 6.1.2.1. Boarfish in Subareas VI, VII, VIII. Landings and discards by year (t), 2001–2012. (Data provided by Working Group members). These figures may not in all cases correspond to the official statistics and cannot be used for management purposes.

Year	Ireland	Denmark	Scotland	Total landings	Estimated Discards	Total Catch inc discards
2001	120	0	0	120	NA	120
2002	91	0	0	91	NA	91
2003	458	0	0	458	10929	11387
2004	675	0	0	675	4476	5151
2005	165	0	0	165	5795	5959
2006	2772	0	0	2772	4365	7137
2007	17615	0	772	18387	3189	21576
2008	21585	3098	0.45	24683	10068	34751
2009	68629	15059	0	83688	6682	90370
2010	88457	39805	9241	137503	6544	144047
2011	20685	7797	2813	31295	5802	37096
2012	55949	19888	4884	80720	6634	87355

Table 6.1.2.2 Boarfish in ICES Subareas VI, VII, VIII. Landings by year (t), 2001–2012 and Subarea where available. (Data provided by Working Group members). These figures may not in all cases correspond to the official statistics and cannot be used for management purposes.

	Denmark	Ireland	Scotland	Total
2001	0	120	0	120
2002	0	91	0	91
2003	0	458	0	458
VI		65		65
VII		393		393
2004	0	675	0	675
VI		292		292
VII		345		345
VIII		38		38
2005	0	165	0	165
VI		10		10
VII		117		117
VIII		38		38
2006	0	2772	0	2772
VI		21		21
VII		2750		2750
VIII		1		1
2007	0	17615	772	18386
V		6		6
VI		93		93
VII		17510	772	18282
VIII		5		5
2008	3098	21584	0	24683
VI		28	0	28
VII		21557		21557
2009	15059	68629	0	83688
VI		45		45
VII		68584		68584
2010	39805	88457	9241	137503
VI		1355	10	1365
VII	39805	87101	9231	136138
2011	7797	20685	2813	31295
VI		26		26
VII	7779	20659	2813	31251
VIII	18			
2012	19888	55949	4884	80720
VI		125		125
VII	18283	55731	4884	78898
VIII	1604	93		1697
Total	**85647**	**277199**	**17710**	**380556**

Table 6.1.2.3. Boarfish in ICES Areas VI, VII, VIII. Landings by year (t), 2001–2012 and Subarea where available. (Data provided by Working Group members). These figures may not in all cases correspond to the official statistics and cannot be used for management purposes.

Year	Denmark	Ireland	Scotland	Total
2001	0	120	0	120
2002	0	91	0	91
2003	0	458		458
VIa		65		65
VIIb		214		214
VIIj		179		179
2004	0	675	0	675
VIa		292		292
VIIb		224		224
VIIId		38		38
VIIj		122		122
2005	0	165	0	165
VIa		10		10
VIIb		105		105
VIIIa		38		38
VIIj		12		12
2006	0	2772	0	2772
VIa		21		21
VIIb		15		15
VIIg		375		375
VIIIa		1		1
VIIj		2360		2360
2007	0	17615	772	18386
Vb2		6		6
VIa		93		93
VIIb		1259		1259
VIIg		120		120
VIIIa		5		5
VIIj		16131	772	16903
2008	3098	21584	0	24683
VIa		28	0	28
VIIb		3		3
VIIg		184		184
VIIj		21370		21370
2009	15059	68629	0	83688
VIa		45		45
VIIb		73		73
VIIc		1		1
VIIg		4912		4912
VIIh		18225		18225
VIIj		45372		45372
2010	39805	88457	9241	137503
VIa		1349	10	1359
VIaS		7		7
VIIb		2258		2258
VIIc		35	4	39
VIIe	2			2
VIIg	672	3649		4321
VIIh	1465	8453	1712	11629
VIIj	37667	72707	7515	117889
2011	7797	20685	2813	31295
VIa		26		26
VIIb		274		274
VIIc		9		9
VIIg		811		811
VIIh	4155	8540	2813	15508
VIIIa	18			18
VIIj	3624	11025		14648
2012	19888	55949	4884	80720
VIa		125		125
VIIb	80	4501	838	5419
VIIc		108	907	1015
VIIg		616		616
VIIh	5837	10579	3139	19554
VIIIa	1604	93		1697
VIIj	12366	39928		52294
Total	**85647**	**277199**	**17710**	**380556**

Table 6.1.2.4. Boarfish in ICES Areas VI, VII, VIII. Discards of boarfish in demersal and non-target pelagic fisheries by year (t), 2003–2012. (Data provided by Working Group members). These figures may not in all cases correspond to the official statistics and cannot be used for management purposes.

Year	Germany	Ireland	Netherlands	Spain	Total
2003		119	1998	8812	10929
2004		60	837	3579	4476
2005		55	733	5007	5795
2006		22	411	3933	4365
2007		549	23	2617	3189
2008		920	738	8410	10068
2009		377	1258	5047	6682
2010		85	512	5947	6544
2011	49	107	185	5461	5802
2012		181	88	6365	6634

Table 6.2.1.1. Boarfish in ICES Subareas VI, VII, VIII. General boarfish age length key produced from 2012 commercial samples. Figures highlighted in grey are estimated.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
7	1	1													
7.5	1	1													
8		1													
8.5		1	1												
9		1	1												
9.5			1												
10			1												
10.5			2	10	3										
11			1	29	14	2	2								
11.5				9	21	21	18	2	2	1					
12				4	17	22	38	12	8						1
12.5					5	9	42	37	14	6	2		1	1	1
13					2	4	31	28	24	12	6	2	3	1	5
13.5					1	3	25	22	21	14	6	5	4	2	11
14							6	8	18	22	8	3	7	1	20
14.5						1	1	2	3	8	1	6	6	6	30
15							1	1		2	2	2	5	2	19
15.5										2				2	19
16															8
16.5															1
17															1

Table 6.2.1.2. Boarfish in ICES Subareas VI, VII, VIII. Sampling intensity by country of commercial landings.

			DK				IRL				SCT			
Year	Q	Area	Landings	Samples	Measured	Allocated	Landings	Samples	Measured	Allocated	Landings	Samples	Measured	Allocated
2007	1	VIa					12	0	0	VIIj_Q2 and VIa_Q4				
	1	VIIIa					5	0	0	VIIj_Q2 and VIa_Q4				
	1	VIIj					5253	0	0	VIIj_Q2 and VIa_Q4	772	0	0	Irish 2007 combined
	2	VIIg					120	0	0	VIIj_Q2 and VIa_Q4				
	2	VIIj					4130	2	197	VIIj_Q2 and VIa_Q4				
	3	VIIb					0	0	0	VIIj_Q2 and VIa_Q4				
	4	Vb2					6	0	0	VIIj_Q2 and VIa_Q4				
	4	VIa					82	1	20	VIIj_Q2 and VIa_Q4				
	4	VIIb					1259	0	0	VIIj_Q2 and VIa_Q4				
	4	VIIj					6748	0	0	VIIj_Q2 and VIa_Q4				
	Total		0	0	0		17615	3	217		772	0	0	
2008	1	VIa					5	0	0	VIIj_Q4				
	1	VIIg					184	0	0	VIIj_Q4				
	1	VIIj					5041	0	0	VIIj_Q4				
	2	VIIj					46	0	0	VIIj_Q4				
	3	VIIj					4067	0	0	VIIj_Q4				
	4	VIa					23	0	0	VIIj_Q4	0.5	0	0	Irish 2008 combined
	4	VIIb					3	0	0	VIIj_Q4				
	4	VIIj					12216	1	152	VIIj_Q4				
	Total		3098	0	0		21584	1	152		0.5	0	0	
2009	1	VIIb					55	0	0	VIIj_Q3				
	1	VIIg					2979	0	0	VIIj_Q3				
	1	VIIh					1971	0	0	VIIj_Q3				
	1	VIIj					10901	2	359	VIIj_Q3				
	2	VIIg					1933	0	0	VIIj_Q3				
	2	VIIh					3169	0	0	VIIj_Q3				
	2	VIIj					2727	0	0	VIIj_Q3				
	3	VIIh					10378	0	0	VIIj_Q3				
	3	VIIj					11423	1	175					
	4	VIa					45	0	0	VIIj_Q4				
	4	VIIb					18	0	0	VIIj_Q4				
	4	VIIh					2707	0	0	VIIj_Q4				
	4	VIIj					20321	6	941					
	Total		15059	0	0		68629	9	1475		0	0	0	
2010	1	VIa									10	0	0	Irish 2010 VIIb_Q1
	1	VIIb					1069	1	102					
	1	VIIg	577	1	77		2392	0	0	VIIj_Q1				
	1	VIIh	1079	0	0	VIIg+VIIj_Q1	326	1	94					
	1	VIIj	32422	2	193		34466	12	1447		2504	0	0	Irish 2010 VIIj_Q1
	2	VIIh					102	0	0	VIIh_Q3				
	2	VIIj	344	0	0	VIIj_Q1								
	3	VIIg					338	0	0	VIIh_Q3				
	3	VIIh	377	0	0	VIIh_Q4	5540	8	1316		548	0	0	Irish 2010 VIIh_Q3
	3	VIIj	2660	0	0	VIIj_Q4	11531	31	3275		2171	0	0	Irish 2010 VIIj_Q3
	4	VIa					1355	1	117					
	4	VIIb					1189	0	0	VIIj_Q4				
	4	VIIc					35	0	0	VIIj_Q4	4	0	0	Irish 2010 VIIj_Q4
	4	VIIe	2	0	0	VIIh_Q4								
	4	VIIg	94	0	0	VIIh+VIIj_Q4	920	0	0	VIIh_Q4				
	4	VIIh	9	3	384		2484	6	715		1165	0	0	Irish 2010 VIIh_Q4
	4	VIIj	2241	2	217		26710	27	2738		2840	0	0	Irish 2010 VIIj_Q4
	Total		39805	8	871		88457	87	9804		9241	0	0	
2011	1	VIIb					39	0	0	VIIj_Q4				
	1	VIIh	32	0	0	VIIh_Q4								
	1	VIIIa	18	0	0	VIIh_Q4								
	1	VIIj	1	0	0	VIIj_Q4	38	0	0	VIIj_Q4				
	2	VIIb					1	0	0	VIIj_Q4				
	3	VIIh					820	0	0	VIIh_Q4	434	0	0	Irish 2011 VIIh_Q4
	3	VIIj					1092	0	0	VIIj_Q4				
	4	VIa					26	0	0	VIIj_Q4				
	4	VIIb					235	0	0	VIIj_Q4				
	4	VIIc					9	0	0	VIIj_Q4				
	4	VIIg					811	0	0	VIIj_Q4				
	4	VIIh	4123	11	1347		7720	3	319		2379	0	0	Irish 2011 VIIh_Q4
	4	VIIj	3623	5	611		9894	8	1789					
	Total		7797	16	1958		20685	11	2108		2813	0	0	
2012	1	VIIb					4365	3	339					
	1	VIIg					616	0	0	IRL_Q3_VIIh				
	1	VIIh	3789	1	150	IRL_Q3_VIIh	1005	0	0	IRL_Q3_VIIh				
	1	VIIj	11403	3	102	IRL_Q1_VIIj	27812	42	4987					
	1	VIIIa	1330	2	214	IRL_Q3_VIIh								
	2	VIIh	208	0	0	IRL_Q3_VIIh								
	3	VIIb					49	0	0	IRL_Q1_VIIb				
	3	VIIh					3176	5	682		1537	0	0	IRL_Q3_VIIh
	3	VIIj					834	2	341					
	4	VIa					125	1	96					
	4	VIIb	80	0	0	IRL_Q1_VIIb	87	0	0	IRL_Q1_VIIb	838	0	0	IRL_Q1_VIIb
	4	VIIc					108	0	0	IRL_Q1_VIIb	907	0	0	IRL_Q1_VIIb
	4	VIIh	1840	4	445	IRL_Q4_VIIh	6398	7	945		1602	0	0	IRL_Q4_VIIh
	4	VIIIa	274	0	0	IRL_Q4_VIIj	93	0	0	IRL_Q4_VIIh				
	4	VIIj	963	2	180	IRL_Q4_VIIj	11281	8	1175					
Total			19888	12	1091		55949	68	8565		4884	0	0	

Table 6.2.1.3. Boarfish in ICES Subareas VI, VII, VIII. Boarfish age length key produced from 2011 commercial samples. Figures highlighted in grey are estimated.

		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
IRL	8	1																		
Q4	8.5																			
VIIh	9																			
	9.5	1	5																	
	10		7	3																
	10.5		6	2		2														
	11		1	3	1	4	2	2												
	11.5				2	9	2	2												
	12					5	4	4	2											
	12.5					2	3	2	2	1	3									
	13					3	3		3	2					1			2		1
	13.5						1	1	1	1	2	3	1			1	1	2		1
	14										1	2	2	1	1	1				1
	14.5									1					1			2		1
	15															1		2		1

		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
IRL	9		1																	
Q4	9.5		1																	
VIIj	10		1		2															
	10.5		1				1													
	11			2	2	2	1	1												
	11.5			1	4	15	8	4	2											
	12				1	12	10	8	7	5		1								
	12.5				1	8	12	6	7	6	4	2								
	13					1	4	8	5	6	5	8	2	2	1	1		1	1	
	13.5						2	1	3	5	2	5	5	5	2	1	4	2	1	6
	14								1	2	1	4	6	2	4	3	1	2	2	12
	14.5									1		2	3	5		5	2	2		14
	15										1	1	1	1		5	4	2	1	19
	15.5															2	1	2	1	19
	16																			8
	16.5																			2
	17																			1

IRL & DNK		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
Q4	7	1																		
VIIh	8	1																		
	9	1	5	1																
	10		18	10	5	4														
	11		1	6	12	20	6	5												
	12				1	13	20	13	6	3	4									
	13					4	9	5	6	8	5	3	2	1	5	1	1	4		3
	14								1	1	3	4	4	2	3	2		4	3	9
	15												1	1	1	4	2	3	2	9
	16																			1

IRL & DNK		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
Q4	7	1																		
VIIJ	8		1																	
	9		1																	
	10		2	2	2		1													
	11			3	6	21	14	5	2											
	12				2	25	25	18	16	12	4	3								
	13					2	9	10	11	12	10	13	7	9	3	3	4	3	2	6
	14								1	5	3	8	9	7	5	9	6	6	2	28
	15										1	1	1	2	1	7	5	4	2	38
	16													1	1					11
	17																			1

Table 6.2.1.4. Boarfish in ICES Subareas VI, VII, VIII. Age length key allocations made to unsampled metiers in 2011.

Country	Area	Quarter	Landed (t)	ALK
IRL	VIIb	1	39	IRL_VIIj_Q4
IRL	VIIj	1	38	IRL_VIIj_Q4
IRL	VIIb	2	1	IRL_VIIj_Q4
IRL	VIIh	3	820	IRL_VIIh_Q4
IRL	VIIj	3	1092	IRL_VIIj_Q4
IRL	VIa	4	26	IRL_VIIj_Q4
IRL	VIIb	4	235	IRL_VIIj_Q4
IRL	VIIc	4	9	IRL_VIIj_Q4
IRL	VIIg	4	811	IRL_VIIj_Q4
IRL	VIIh	4	7720	IRL_VIIh_Q4
IRL	VIIj	4	9894	IRL_VIIj_Q4
DNK	VIIh	1	32	Combined IRL&DNK (1.0cm)_VIIh_Q4
DNK	VIIIa	1	18	Combined IRL&DNK (1.0cm)_VIIh_Q4
DNK	VIIj	1	1	Combined IRL&DNK (1.0cm)_VIIj_Q4
DNK	VIIh	4	4123	Combined IRL&DNK (1.0cm)_VIIh_Q4
DNK	VIIj	4	3623	Combined IRL&DNK (1.0cm)_VIIj_Q4
SCT	VIIh	3	434	IRL_VIIh_Q4
SCT	VIIh	4	2379	IRL_VIIh_Q4

Table 6.2.1.5. Boarfish in ICES Subareas VI, VII, VIII. Age length key, for years up to and including 2010, produced from combined commercial and survey samples. Shaded portion indicates commercial fishery size and age range.

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	28	29
2.5	3																												
3	10																												
3.5	2																												
4	1																												
5		2																											
5.5		7																											
6		5																											
6.5		6	2																										
7		5	3																										
7.5		4	3																										
8			5	1																									
8.5			17	6																									
9		1	7	9	1																								
9.5			3	11	6																								
10			1	6	17	7	1																						
10.5			1	1	14	10	1																						
11					13	15	7	2																					
11.5				2	2	8	7	4	1																				
12						3	14	3	5																				
12.5					1	2	5	8		4	3	1																	
13							3	3	4	4	2	1	1	1			1												
13.5								3	3	2	3	1	1	2		1	1			1	1								1
14										4	3	1	3		1		1							1	1				
14.5								1		2	2		2	2	3				2		1	2							
15											1				1	1		1	1		1	1	1		1			1	
15.5											1	1	3		1		1			1		1			1		1	1	
16																				1			1	1					
16.5																1			1		1			1		2			
17																		1	1			2	3		2				
17.5																							1						
18																											1		
23																													

Table 6.2.1.6. Boarfish in ICES Subareas VI, VII, VIII. Proxy catch numbers-at-age of the international catches (raised numbers in '000s) for the years 2007-2012.

	2007	2008	2009	2010	2011	2012
1	0	0	1575	2415	0	28
2	352	5488	15043	11229	2894	893
3	2114	21140	65744	72709	41913	5467
4	40851	105575	338931	294382	28148	41278
5	48915	141300	475619	567689	30116	110272
6	62713	195339	543707	878363	175696	146582
7	26132	104031	307333	522703	143967	492078
8	29766	66570	172783	293719	107126	365840
9	56075	53159	155477	276672	77861	271916
10	44875	46893	130148	232122	60022	173486
11	14019	15289	42521	78588	46079	69396
12	32359	21178	61350	114600	40468	40968
13	4848	11854	39609	59932	24352	58888
14	16837	13570	31569	59060	19724	30277
15+	109481	112947	196967	349320	157707	217260

Table 6.2.2.1. Boarfish in ICES Subareas VI, VII, VIII. Length-frequency distributions of the international catches (raised numbers in '000s) for the years 2007-2012.

TL (cm)	2007	2008	2009	2010	2011	2012	Total
6	0	0	0	156	0	0	156
6.5	0	0	0	439	0	0	439
7	0	0	0	1090	522	56	1667
7.5	0	0	1354	1574	0	0	2928
8	0	0	677	375	1345	185	2581
8.5	0	0	0	1082	0	555	1637
9	0	0	677	5382	851	555	7464
9.5	0	7473	17367	7883	7012	641	40375
10	9609	11209	54130	29410	33243	2791	140392
10.5	0	52308	174796	130889	15848	6132	379974
11	84555	63517	343283	361774	70615	24571	948316
11.5	0	59781	321637	655875	93487	81928	1212708
12	44199	119561	297737	739025	189434	264888	1654845
12.5	0	70990	207739	564347	114904	398772	1356751
13	82633	52308	147965	353484	133539	419060	1188989
13.5	0	29890	149314	246146	51235	307533	784119
14	117224	22418	105782	224611	50857	176710	697602
14.5	0	14945	71273	127711	25309	89726	328964
15	65338	33627	47816	125463	25569	52791	350603
15.5	0	11209	13082	81386	5473	25065	136215
16	13452	11209	19397	24256	4181	13149	85644
16.5	0	3736	4061	6209	2280	2738	19024
17	0	3736	677	1913	456	827	7609
17.5	0	0	0	0	0	0	0
18	0	0	0	283	0	0	283

Table 6.3.2.2 Boarfish in ICES Subareas VI, VII, VIII. IBTS length-frequency data.

WCSGFS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	ML	ML mature	Total	Total mature
1986								1													8.0		1	0
1987								1	1	2	1										9.7	10.2	4	3
1988				1																	4.0		1	0
1989							1														7.0		1	0
1990				1		1	1	2	24	55	50	43	12	1							10.7	11.1	188	160
1991						1	1	9	38	183	267	317	48	16							11.2	11.3	877	829
1992						1		10	39	468	1145	4001	1627	486							12.0	12.1	7775	7726
1993							4		3	9	60	155	73	16		1					12.0	12.1	319	313
1994									1	1	1			1							11.0	11.7	2	2
1995									8	37	194	294	398	199	22						12.5	12.5	1150	1143
1996				2		4	3				1	55	610	1575	304						13.8	13.8	2553	2544
1997			4			1	7	9	4	6	25	109	203	157	41	4					12.9	13.1	568	544
1998				1		1	5	2		1	2		3								8.8	11.8	15	6
1999			1			2	5	1	1		1	2	1								8.2	12.0	14	4
2000							2	2	39	110	216	288	183	93	46	6					12.0	12.1	983	940
2001		1						1	4	15	28	59	134	240	103	10	4				13.5	13.6	599	593
2002						1	8	2	1	82	742	3211	5601	5772	1497	167	1				13.2	13.3	17085	17073
2003			1				3	52		53	281	1473	3066	4895	3083	309	28				13.7	13.8	13244	13188
2004				1			2	2	43	82	743	4569	8600	9514	5693	948	84				13.6	13.6	30280	30232
2005		2					24	3	23	25	110	435	1085	1708	792	130	6				13.6	13.7	4343	4291
2006		1	2	1		1	4		10	218	232	452	1396	2853	2051	435	72				13.9	13.9	7726	7707
2007			2	2		2	1	3	21	159	780	2923	5194	6888	5283	1523	116				13.8	13.8	22897	22866
2008		1	1			16	37	36	187	468	1395	3213	9893	22758	18399	6288	575	71			14.1	14.2	63338	63060
2009			1			1		5	53	2443	2093	441	331	287	246	129	10				11.2	11.2	6038	5979
2010											530	1443	1384	1357	828	149	29				13.2	13.2	5720	5720
2011		1	4	1		1	5	254	1015	2034	7613	18918	14479	6445	2006	237	23				12.4	12.4	53034	51753
2012			1			1	2		103	9	1267	6545	26337	29361	27333	15857	1505	497			14.2	14.2	108817	108710

SPPGFS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	ML	ML mature	Total	Total mature
2001		1		1	1	2		44	5	52	133	162	667	1129	230	40					13.3	13.5	2467	2413
2002									1	4	90	212	791	843	313	60					13.5	13.5	2314	2313
2003						1		3	15	22	21	62	268	426	249	51	2	1			13.8	13.8	1121	1102
2004		1				5	2		4	5	18	100	312	483	319	43	1				13.8	13.9	1293	1281
2005		1		1	6	1	18	10	9	14	7	101	530	935	705	226	18				14.0	14.2	2581	2536
2006			1	1	6	91	89	21	34	75	27	45	335	670	555	197	10	1			13.3	14.1	2158	1914
2007					3	4	9	15	12	9	27	25	72	151	144	26	4				13.4	13.9	501	458
2008		1				1	13	7	16	13	55	106	237	457	302	78	5				13.7	13.8	1292	1254
2009		6	5		2	7	8	1		1	154	318	924	1201	1172	324	7				13.9	14.0	4130	4101
2010	1			1	5	14	3	1	5	2	31	284	521	717	459	123	10				13.7	13.8	2178	2148
2011								3	16	18	5	147	671	792	429	122	13		2		13.8	13.8	2220	2200
2012				1	1			2	2	1	8	70	369	468	218	66	3				13.8	13.9	1208	1202

IGFS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	ML	ML mature	Total	Total mature
2003		1	32	22	7	22	129	172	879	2942	2322	1325	3822	4628	2898	896	163	38			12.7	13.0	20299	19035
2004		23	63	34	8	96	532	1431	369	344	410	2253	4320	4698	3966	1017	87	2	1		12.9	13.7	19654	17098
2005		8	59	52	20	203	1024	585	288	636	341	3463	11457	11348	7955	1744	382	2	1		13.4	13.7	39569	37330
2006	5	60	68	48	35	212	969	621	2046	4190	8044	7946	24208	42119	32168	12296	2454	532			13.7	13.9	138021	133957
2007	1	6	44	18	31	501	923	1251	1638	1166	2510	3581	8275	10740	7093	1934	92				12.9	13.5	39804	35391
2008			26	18	23	127	672	531	2095	13780	17664	19268	16980	19484	15953	8789	1747	76	1		12.8	12.9	117231	113741
2009		3	80	76	25	94	228	486	1000	1139	9081	7749	5138	6921	5592	1084	68	1			12.5	12.8	38763	36772
2010		6	42	3	18	199	272	463	920	393	7914	34236	28611	16063	8161	1974	433				12.8	12.9	99709	97784
2011		6	14	5	4	189	772	586	555	670	2578	20171	22082	10829	5298	2207	266	9	6		12.9	13.0	66247	64116
2012		7	36	20	10	131	271	378	702	2144	1183	11105	34010	22742	10906	3903	525	4			13.3	13.4	88077	86521

EVHOE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	ML	ML mature	Total	Total mature
1997		5	11	7	17	197	2659	5020	3719	3598	4429	12065	16651	7198	3455	501	18	1			11.8	12.7	59548	47915
1998		1	4	26	76	2093	18283	8631	6125	5966	7095	11730	14078	9260	5076	934	8			1	10.6	12.6	89387	54148
1999			13	52	33	245	11177	26610	23947	6684	2899	4709	7868	6160	1353	267	7				9.5	12.3	92023	29947
2000		17	79	120	8	1504	26894	17674	9836	21967	16382	29585	36853	16522	5397	989	75				10.8	12.2	183903	127769
2001		1	45	687	489	913	21297	37171	13276	28355	31514	18309	12232	6471	3186	1270	81	4			10.0	11.5	175303	101422
2002		2	18	23	11	547	9631	29874	17777	13290	9470	9697	9751	6268	2484	641	37	1	1		9.9	11.9	109522	51639
2003			17	47	17	57	426	1655	7142	20018	24842	20989	21263	14493	7086	1550	36				11.8	12.1	119639	110277
2004			33	512	378	123	1248	1419	1307	1083	3102	7308	7224	6353	7866	3630	241	5			12.7	13.5	41833	36813
2005		2	93	975	1285	146	1100	2326	1229	1553	3183	13398	15758	9834	6010	1658	117	70			12.3	13.1	58738	51580
2006	1	26	112	79	75	15510	37566	10750	3622	2127	1521	1955	4131	3955	2535	921	94	2	12		8.2	13.1	84994	17253
2007		8	187	467	234	1503	22689	126065	64536	6341	6731	5431	6004	5911	4238	1409	118	11			8.8	12.5	251882	36193
2008		3	434	2807	827	5341	53189	247297	165392	163200	69382	38434	18390	17258	9178	3490	745	6	1		9.3	11.1	795371	320083
2009		6	128	194	72	1496	19769	35819	5264	3913	9556	12269	9402	10831	6720	775	38	1			10.0	12.7	116252	53505
2010		21	529	116	154	5755	46438	74986	27175	11952	37420	58313	34737	33774	14626	1561	249	8	1		10.4	12.5	347814	192641
2011		60	95	215	5	541	2247	8368	15256	33221	30237	50384	56559	36673	11867	3082	573	159	47		12.0	12.4	249590	222803
2012		9	145	584	137	2922	28865	26816	6124	11739	13606	22369	37135	44082	19963	4893	127	1			11.4	13.1	219516	153914

SPNGFS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	ML	ML mature	Total	Total mature
1991		1			31	690	1311	313	49	9	6	7	7	4				6			7.0	12.7	2433	39
1992		57	38	9	178	3290	2743	282	48	10	8	69	162	390	779	246	95				8.2	14.7	8404	1760
1993		57	1206	488	97	3730	3753	421	105	54	7	4	8	3	2						6.0	10.8	9934	77
1994	1	40	33		342	4789	10162	8920	3195	53	106	20	9	12	1						7.4	11.1	27685	202
1995		84	108	4	342	3063	2157	220	84	65	58	105	105	90	20	4					6.7	12.4	6510	447
1996		218	537	143	245	4457	4449	267	820	722	82	145	126	219	96	39	2				7.0	11.6	12566	1431
1997	2	102	809	441	235	3458	6824	2189	1923	534	156	353	161	88	3						7.2	11.3	17277	1295
1998	3	2	7	4	49	1920	4685	1815	337	153	125	88	147	135	86	13	2	3			7.5	12.4	9573	752
1999		6	59	13	134	2736	3010	193	106	83	109	143	390	645	402	69					8.1	13.6	8098	1841
2000		7	3729	2046	17	554	1947	489	277	486	756	1252	999	1021	199	34	13				7.4	12.4	13827	4760
2001		68	4	1	153	3241	5085	659	225	206	205	236	692	407	120	22	9				7.7	12.7	11331	1896
2002		4	20		133	2333	2013	284	50	58	54	60	231	314	72	9					7.5	13.2	5634	798
2003		4	950	567	4	77	221	57	39	28	16	22	17	23	16	5	1				4.7	12.5	2047	128
2004		6	22	4	43	2289	3808	443	110	83	58	219	931	776	303	2	1				8.5	13.3	9097	2372
2005		16	451	25	9	754	1007	207	85	102	30	54	257	218	90	44	2				7.8	13.1	3349	797
2006		14	156	160	50	2238	8913	4507	175	94	9	36	229	419	169	9	2				7.4	13.5	17181	968
2007		49	40	1	111	3025	6620	1099	129	260	81	7	93	215	89	21	3				7.2	12.4	11843	768
2008	7	4	92	247	1	936	1561	1326	234	1483	304	537	11	833	201	186	11				9.2	11.9	7974	3566
2009	1	17	53	125	9	2582	3816	4105	119	250	45	142	59	819	120	17	1	1			7.8	13.1	12283	1456
2010		55	102	5	232	13090	22032	3169	1160	1056	89	82	179	1007	1981	518	9				7.5	13.6	44766	4920
2011		29	260	105	46	2805	5511	1278	148	340	145	100	144	591	724	134	3	1			7.9	13.5	12364	2182
2012		29	132	35	556	7550	7844	1364	88	53	59	170	1051	2394	1553	432	21				8.4	14.1	23331	5734

Table 6.6.2.1. Boarfish in ICES Subareas VI, VII and VIII. IBTS length-frequency data converted to age-structured index by application of the 2010 common ALK rounded down to 1cm length classes.

All	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1997	9186	11460	5356	4603	4209	7331	6050	4331	4970	4375	1498	2491	1741	1248	635	1242	161	676	635	3814
1998	17475	19641	6886	6423	5693	7515	5791	3814	4860	4439	1481	2883	1654	1644	685	1240	236	917	685	4965
1999	11838	33029	20031	8826	3580	3421	2837	1990	2911	2552	804	1716	1045	1010	320	705	80	539	320	2435
2000	19340	29071	12974	18627	16220	19669	14950	10117	11553	9928	3345	5427	3955	2717	1310	2709	265	1470	1310	7757
2001	20344	44451	20694	25753	22184	16593	9665	4839	5137	4484	1492	2471	1545	1362	643	1109	175	824	643	4482
2002	10040	33131	18597	13158	9120	9171	6846	4380	6006	5313	1699	3476	2053	2046	696	1430	202	1115	696	5313
2003	840	4714	8356	20850	19443	18478	13092	7863	10801	10051	3279	7063	3662	4270	1598	2792	629	2439	1598	12890
2004	5958	5660	2092	2537	3567	8255	7560	5288	8479	8618	2871	6954	2968	4378	1924	2576	866	2794	1924	16191
2005	4201	4323	2012	2784	3836	9869	9393	6931	10296	9875	3269	7332	3684	4419	1814	2913	759	2642	1814	14728
2006	44120	35631	8054	7238	6703	8802	9417	6528	14774	15648	4994	14441	5398	9659	3847	4781	1967	6478	3847	37015
2007	24531	128029	67188	19124	7326	8707	7376	4824	8405	8454	2739	7014	2967	4520	1748	2495	799	2784	1748	15325
2008	43985	262478	172674	148047	91323	53729	31280	15702	23250	22959	7433	17778	7213	11602	5022	6177	2310	7992	5022	45589
2009	18107	42788	14748	10829	12257	14366	9760	5252	7847	7656	2476	5816	2443	3766	1259	2049	642	2128	1259	11324
2010	58552	98227	37475	25665	30828	52503	37174	21833	27440	24593	8035	15093	8215	8983	3253	6110	1257	4997	3253	25820
2011	8615	17617	17110	34003	34910	52378	39952	26259	31789	27728	9181	16113	10503	8764	3850	7350	1012	5048	3850	26631
2012	32050	40410	12771	13406	14205	27201	28554	21680	36693	35756	11588	28599	13608	17833	7714	10766	2944	11650	7714	64807
EVHOE	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20+**
1997	1876	6003	3741	3911	3938	7065	5867	4218	4832	4259	1461	2428	1699	1214	623	1215	159	659	623	3737
1998	12977	15997	6248	6247	5591	7435	5732	3777	4806	4386	1463	2843	1635	1619	676	1224	232	904	676	4888
1999	7576	31223	19915	8732	3499	3308	2715	1905	2720	2357	743	1540	975	893	285	647	62	474	285	2102
2000	17676	27730	12586	17986	15525	18740	14297	9737	11041	9490	3208	5160	3797	2556	1266	2604	253	1384	1266	7385
2001	14389	41313	20357	25467	21921	16211	9247	4525	4543	3951	1332	2057	1322	1098	578	959	153	684	578	3884
2002	6719	31728	18455	12784	8389	7115	4767	2851	3429	3018	994	1806	1123	1009	421	796	117	573	421	2964
2003	509	3993	7348	18371	17276	16113	10798	6270	7620	6852	2267	4294	2501	2456	1009	1838	326	1387	1009	7340
2004	1265	1976	1261	1722	2227	4124	3228	2061	2871	3058	1066	2426	939	1509	901	917	382	1142	901	7311
2005	2102	2603	1497	2098	3015	7160	5992	4177	5301	4873	1642	3144	1796	1776	833	1368	285	1065	833	6107
2006	35834	26593	4803	2199	1386	1489	1332	947	1521	1484	485	1170	557	725	311	445	125	464	311	2596
2007	16818	122140	65369	16986	4919	4316	2967	1715	2452	2392	788	1802	820	1124	484	678	204	715	484	4049
2008	41611	258758	168378	134061	77106	37738	18750	8277	9132	8183	2660	4868	2458	2992	1226	1876	492	1919	1226	10417
2009	13338	36829	12194	5626	5982	7788	5443	3054	4443	4230	1364	3079	1382	1965	618	1114	309	1064	618	5485
2010	33601	83903	35048	21678	23503	34210	23037	12643	16303	14519	4647	9008	4716	5551	1689	3457	690	2957	1689	14298
2011	2212	12471	14982	28729	26114	31844	23915	15535	19473	16964	5542	10176	6534	5663	2262	4513	597	3197	2262	16235
2012	20089	34348	11535	11098	10795	14979	13308	9004	15662	14714	4598	11467	5540	7325	2325	4142	920	4164	2325	20439
IGFS+WCSGFS+EVHOE	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20+**
2003	636	4552	8306	20803	19406	18414	13013	7804	10668	9916	3237	6942	3612	4190	1573	2752	617	2393	1573	12654
2004	1685	3414	1912	2444	3481	8017	7255	5037	8031	8189	2735	6610	2796	4164	1860	2446	838	2683	1860	15644
2005	2930	3604	1895	2694	3773	9738	9200	6777	9949	9514	3154	7004	3553	4203	1731	2801	721	2505	1731	13978
2006	36687	28176	6830	7100	6633	8714	9277	6421	14479	15337	4898	14144	5288	9457	3779	4686	1933	6356	3779	36365
2007	17873	124020	66810	18929	7205	8648	7322	4790	8309	8353	2708	6917	2932	4453	1729	2464	788	2746	1729	15126
2008	42240	260577	172031	147113	90691	53328	31023	15587	22918	22641	7344	17496	7113	11395	4967	6101	2285	7861	4967	44972
2009	13607	37705	13658	10616	12063	14060	9426	5030	7283	7072	2296	5275	2243	3396	1141	1878	582	1909	1141	10185
2010	33976	84649	35967	24858	30441	52245	36921	21671	26982	23992	7828	14456	8055	8546	3060	5910	1145	4712	3060	24053
2011	2884	13954	16666	33742	34724	52174	39716	26089	31387	27290	9039	15699	10356	8486	3752	7213	958	4882	3752	25707
2012	20395	35049	12386	13340	14140	26984	28191	21406	35924	34955	11342	27840	13323	17314	7548	10525	2861	11338	7548	63197
SPNGFS	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20+**
1997	7306	5446	1609	681	249	203	121	67	69	56	18	22	18	11	4	11	0	6	4	23
1998	4493	3640	638	175	101	79	58	37	54	53	17	40	19	25	9	15	4	14	9	77
1999	4258	1802	116	93	80	112	121	85	191	195	61	175	70	117	35	58	18	65	35	333
2000	1661	1325	347	518	553	750	537	315	443	379	116	237	139	146	37	91	10	78	37	325
2001	5952	3099	308	205	161	197	190	148	199	175	58	114	77	62	25	53	6	34	25	169
2002	3315	1395	104	54	43	55	63	47	98	88	26	71	37	46	10	25	3	24	10	97
2003	203	155	38	26	16	14	10	5	9	9	3	7	3	4	2	2	1	3	2	15
2004	4267	2243	177	82	68	171	219	186	303	279	89	209	118	124	37	85	14	63	37	294
2005	1253	701	108	78	46	50	60	51	84	78	25	59	33	35	15	24	4	22	15	116
2006	7297	7378	1191	85	34	36	56	44	116	112	33	100	43	68	14	32	8	35	14	154
2007	6646	3990	367	180	106	37	30	18	55	54	16	50	20	35	8	15	4	20	8	92
2008	1736	1886	629	908	597	329	178	62	202	183	47	158	53	122	28	36	10	81	28	352
2009	4487	5077	1085	168	104	79	71	26	174	155	37	147	56	113	9	34	6	58	9	194
2010	24558	13572	1504	792	346	101	85	41	222	365	132	436	76	306	146	130	91	206	146	1347
2011	5730	3656	432	244	163	94	77	38	140	182	61	198	48	140	50	59	33	84	50	493
2012	11653	5359	383	62	55	160	276	202	620	657	201	638	228	441	140	198	73	266	140	1382

Table 6.6.3.1. Boarfish in ICES Subareas VI, VII, VIII. Pseudo-cohort derived estimates of fishing mortality (F) and total mortality (Z), in comparison with total catch per year. Pearson correlation coefficient of F vs. catch (tonnes) indicated.

Age	2007	2008	2009	2010	2011	2012	2007	2008	2009	2010	2011	2012
	Raised numbers						ln (raised numbers)					
1	0	0	1575	2415	0	28	0	0	7	8	0	3
2	352	5488	15043	11229	2894	893	6	9	10	9	8	7
3	2114	21140	65744	72709	41913	5467	8	10	11	11	11	9
4	40851	105575	338931	294382	28148	41278	11	12	13	13	10	11
5	48915	141300	475619	567689	30116	110272	11	12	13	13	10	12
6	62713	195339	543707	878363	175696	146582	11	12	13	14	12	12
7	26132	104031	307333	522703	143967	492078	10	12	13	13	12	13
8	29766	66570	172783	293719	107126	365840	10	11	12	13	12	13
9	56075	53159	155477	276672	77861	271916	11	11	12	13	11	13
10	44875	46893	130148	232122	60022	173486	11	11	12	12	11	12
11	14019	15289	42521	78588	46079	69396	10	10	11	11	11	11
12	32359	21178	61350	114600	40468	40968	10	10	11	12	11	11
13	4848	11854	39609	59932	24352	58888	8	9	11	11	10	11
14	16837	13570	31569	59060	19724	30277	10	10	10	11	10	10
15+	109481	112947	196967	349320	157707	217260	12	12	12	13	12	12
Z							0.19	0.35	0.35	0.34	0.28	0.31
F (Z-M), where M = 0.16							0.03	0.19	0.19	0.18	0.12	0.15
Catches (t)							21576	34751	90370	144047	36937	86414
Correllation coefficient landings vs. F							0.61					

Table 6.6.4.1. Boarfish in ICES Subareas VI, VII, VIII. Acoustic survey biomass estimates for 2011 -2013.

2011 *MFV Felucca* - 24 hour operations

	Abun (mil)	Biomass (t)	%
Total estimate			
Definitely	7,049	393,893	86.4
Probably	1,134	62,222	13.6
Mixture	-	-	-
Total estimate	**8,183**	**456,115**	**100**
Possibly			
CV TSB	17.5	17.6	
SSB Estimate			
Definelty	7,019	393,312	86.4
Probably	1,126	62,063	13.6
Mixture	0	0	0.0
SSB estimate	**8,145**	**455,375**	**100**
Possibly	-	-	

2012 *MFV Father McKee* - daylight only (04:00 - 24:00) operations

	Abun (mil)	Biomass (t)	%
Total estimate			
Definitely	11,684	708,019	82.0
Probably	2,072	123,723	14.3
Mixture	501	31,704	3.7
Total estimate	**14,257**	**863,446**	**100**
Possibly	16	1,017	
CV TSB	10.6	10.7	
SSB Estimate			
Definelty	11,615	706,582	82.0
Probably	2,050	123,286	14.3
Mixture	500	31,676	3.7
SSB estimate	**14,165**	**861,544**	**100**
Possibly	16	1,017	

2013 *MFV Felucca* - daylight only (04:00 - 24:00) operations

	Abun (mil)	Biomass (t)	%
Total estimate			
Definitely	8,834	431,571	98.1
Probably	240	7,187	1.6
Mixture	17	1,139	0.3
Total estimate	**9,091**	**439,897**	**100**
Possibly	-	-	
CV TSB	17.5	16.7	
SSB Estimate			
Definelty	8,120	416,124	98.3
Probably	179	5,895	1.4
Mixture	17	1,139	0.3
SSB estimate	**8,316**	**423,158**	**100**
Possibly	-	-	

Biomass derived using a modelled boarfish TS-Length relationship (-66.2dB).

Table 6.6.5.1. Boarfish in ICES Subareas VI, VII, VIII. Key parameter estimates from all runs. CV(TSB_{2013}) is the coefficient of variation of the estimated total stock biomass in 2013. Posterior parameter distributions are provided in Figures 6.6.5.8, 6.6.5.9, 6.6.5.10.

Run	r	K	F_{MSY}	B_{MSY}	TSB_{2013}	CV(TSB_{2013})
1	0.481	731549	0.241	365775	500945	0.156
2	0.493	835581	0.247	417791	633617	0.44
3	0.467	634469	0.233	317234	472169	0.153
4	0.466	865294	0.233	432647	665705	0.555
1.1	0.552	768400	0.276	384200	493886	0.161
2.1	0.551	898583	0.275	449292	604780	0.444
3.1	0.528	660356	0.264	330178	470985	0.157
4.1	0.517	828299	0.259	414150	607527	0.434
2.2	0.459	911209	0.229	455605	653668	0.436

Table 6.6.5.2. Boarfish in ICES Subareas VI, VII, VIII. Estimates of total stock biomass and F for run 2.2.

Year	Low TSB	Mean TSB	High TSB	Low F	Mean F	High F
1991	185405	402420	865890	0	0	0
1992	294500	599420	1262950	0	0	0
1993	349105	718212	1513975	0	0	0
1994	408708	840629	1800900	0	0	0
1995	363405	740344	1550950	0	0	0
1996	361600	750564	1594975	0	0	0
1997	328002	660890	1401000	0	0	0
1998	422200	858262	1801975	0	0	0
1999	333402	675083	1407975	0	0	0
2000	282600	573745	1218975	0	0	0
2001	301502	593448	1249975	0	0	0
2002	277102	548569	1165000	0	0	0
2003	271905	535535	1116000	0.01	0.024	0.042
2004	369702	729284	1531000	0.003	0.008	0.014
2005	361408	704629	1469000	0.004	0.01	0.016
2006	394618	768741	1612000	0.004	0.011	0.018
2007	323300	637403	1321975	0.016	0.038	0.067
2008	404700	781097	1606000	0.022	0.05	0.086
2009	398400	761783	1571975	0.057	0.134	0.227
2010	606225	1153265	2371900	0.061	0.141	0.238
2011	509708	974025	2007975	0.018	0.043	0.073
2012	605610	1084655	2194975	0.04	0.09	0.144
2013	331202	653668	1365000	0.065	0.154	0.267

Table 6.7.1. Boarfish in ICES Subareas VI, VII, VIII. Projection table. Basis: Catch (2013) = 88 448 thousand tonnes (EU TAC = 82 000 t and average discards 2003-2012 = 6 448 t). Note that for F projections, the fishing mortality is fixed and the credible intervals for catch (95% CI) represent the uncertainty in biomass; for fixed catch projections credible intervals on F represent the uncertainty in biomass.

Projection	F_{2014}	F_{2014} 95% CI	Catch 2014	Catch 2014 95% CI	TSB_{2015}	TSB_{2015} 95% CI	Probability $TSB_{2015}<B_{trigger}$	Probability $TSB_{2015}<B_{lim}$
F_{MSY}	0.23	-	133957*	49330-318500	580672	190800-1388000	0.2529	0.0144
F_{lim}	0.367	-	200249	73740-476100	519601	172400-1201000	0.3465	0.0176
F_{pa}	0.179	-	106904	39370-254200	613004	203600-1453000	0.2166	0.013
F_{01}	0.13	-	79478*	29270-188900	643106	212700-1517000	0.1814	0.008
Zero catch	0	0-0	0	-	729252	235300-1742000	0.1224	0.0074
Status quo catch	0.141	0.05-0.349	88448	-	629760	172100-1554000	0.227	0.0156
20% catch increase	0.172	0.075-0.583	106138	-	617487	151600-1574000	0.2521	0.0206
20% catch decrease	0.112	0.05-0.349	70758	-	652967	184000-1629000	0.2068	0.0126

* Note that these values differ slightly (<1%) to that presented in plenary due to MCMC sampling. The random seed is now fixed to prevent this occurring.

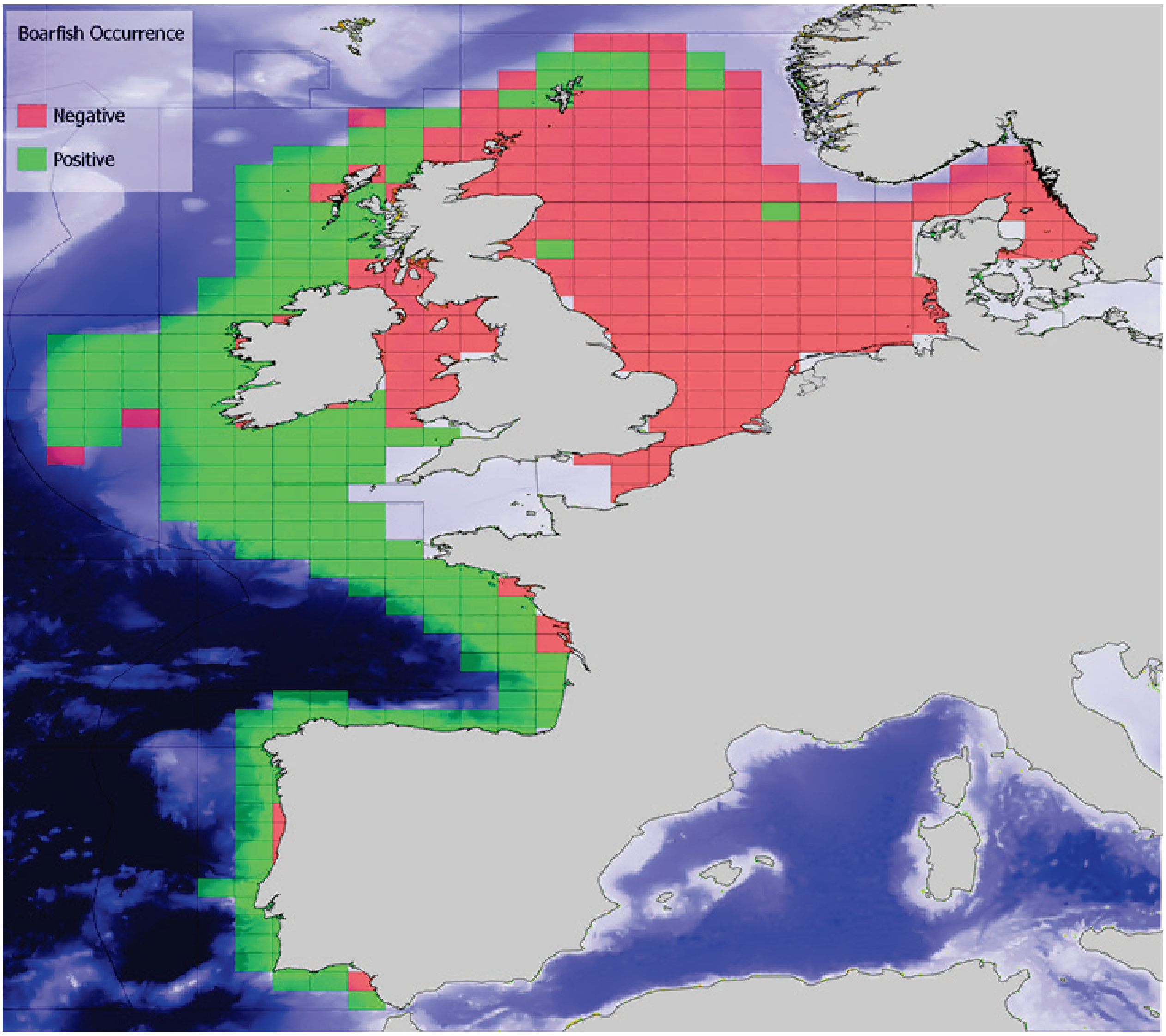

Figure 6.1. Boarfish in ICES Subareas VI, VII, VIII. Distribution of boarfish in the NE Atlantic area based on presence and absence in IBTS surveys.

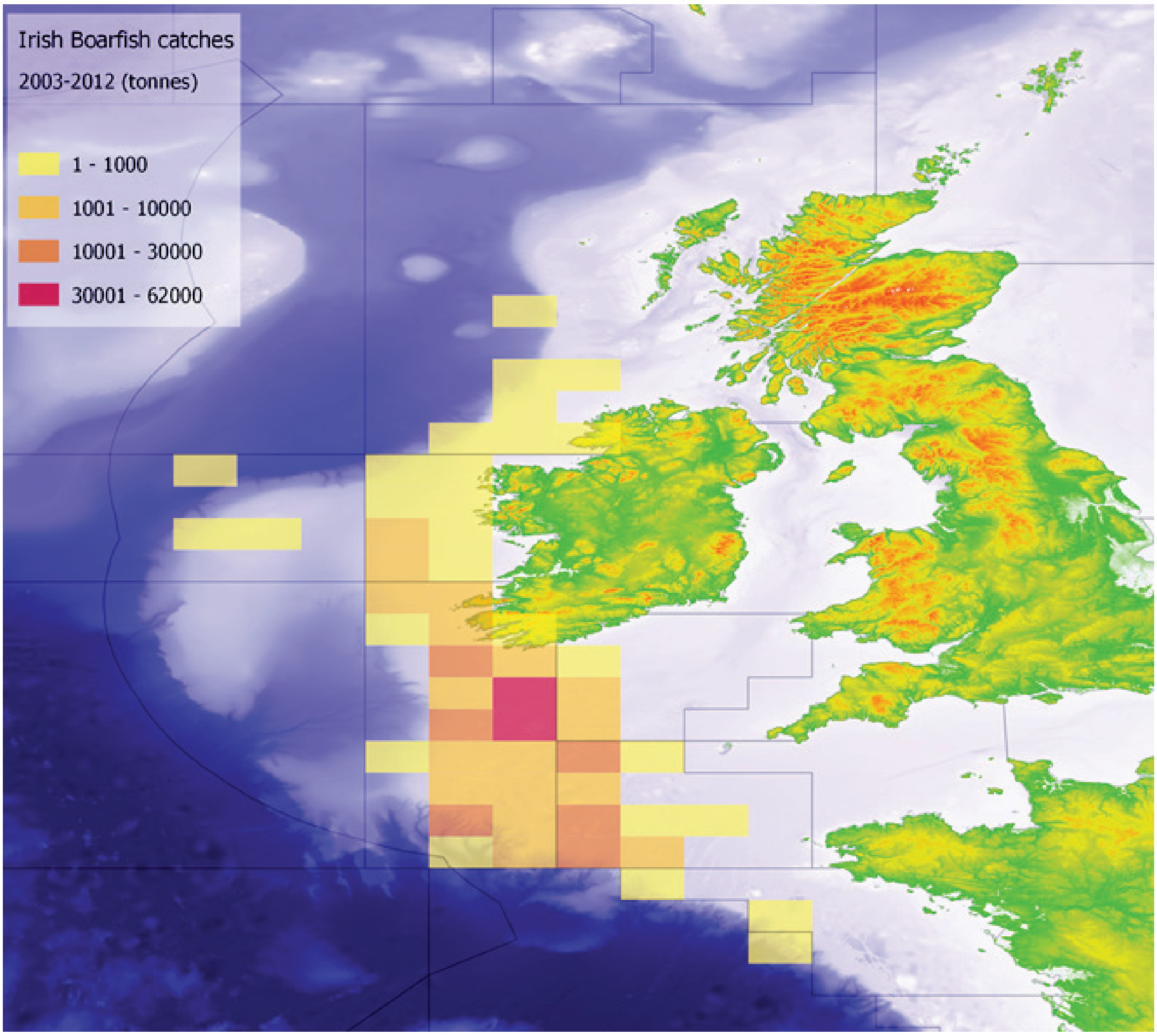

Figure 6.2. Boarfish in ICES Subareas VI, VII, VIII. Combined Irish boarfish landings 2003-2012 by ICES rectangle.

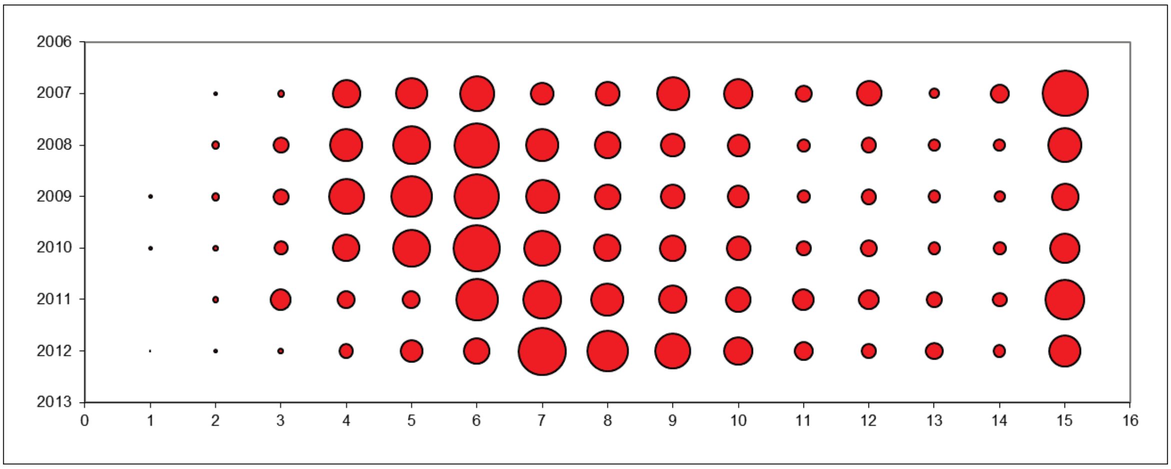

Figure 6.2.1.1. Boarfish in ICES Subareas VI, VII, VIII. Catch numbers-at-age standardised by early mean. 15+ is the plus group.

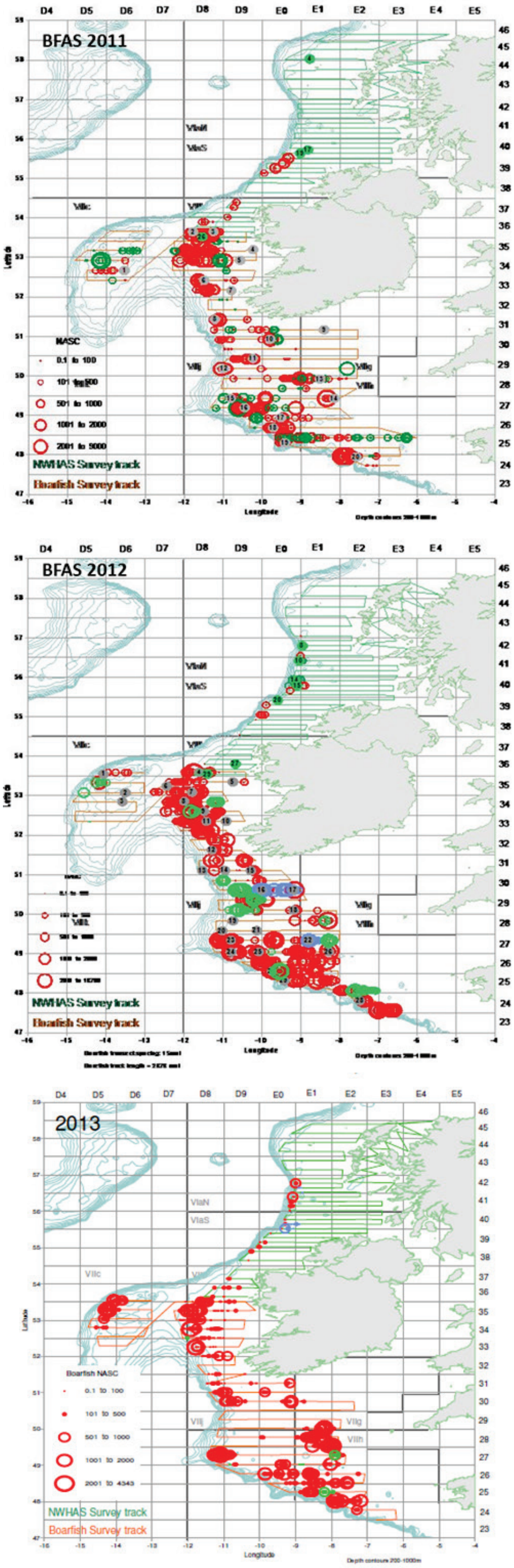

Figure 6.3.1.1. Boarfish in ICES Subareas VI, VII, VIII. Boarfish acoustic survey track and haul positions from acoustic survey 2011-2013.

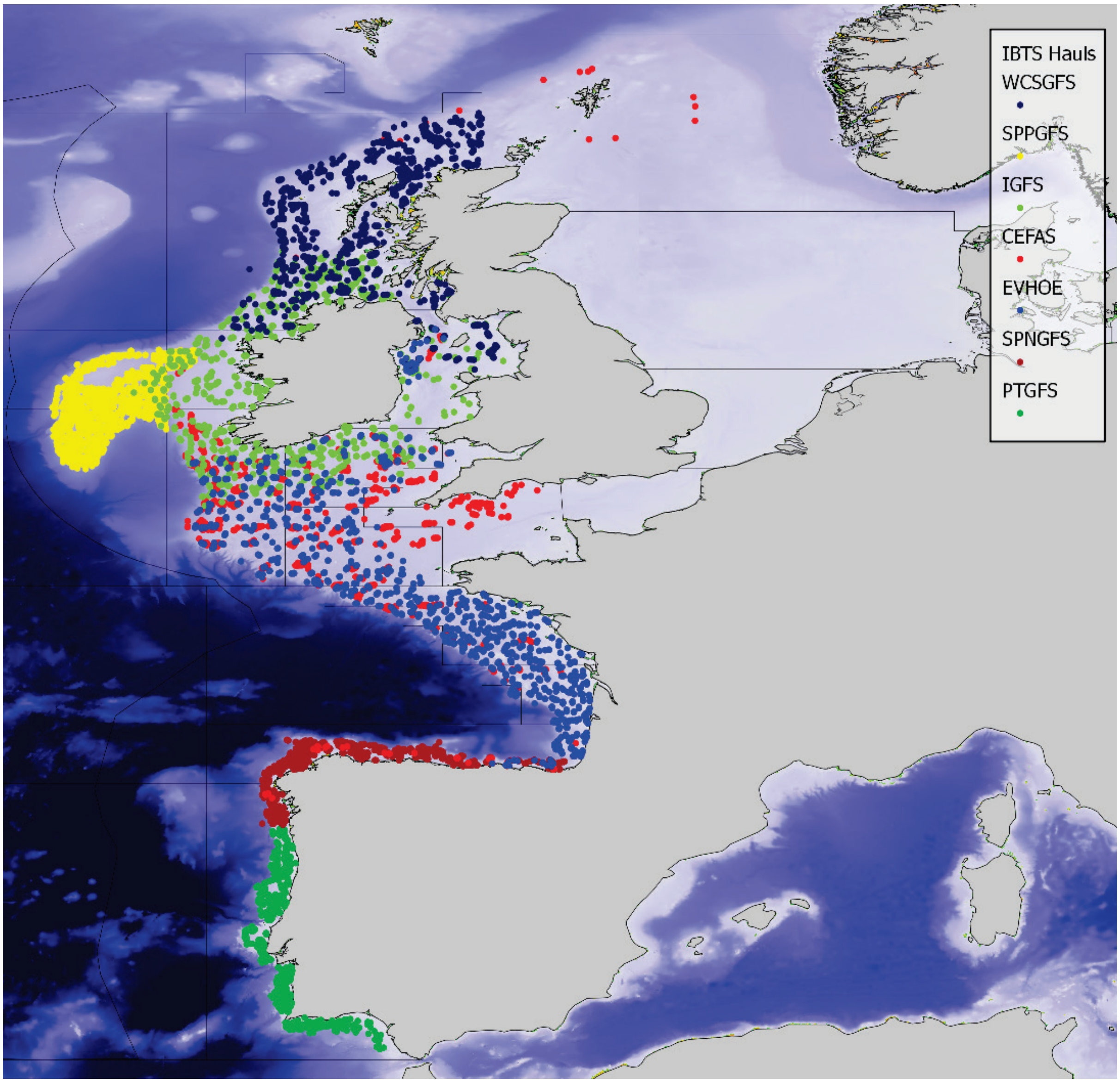

Figure 6.3.2.1. Boarfish in ICES Subareas VI, VII, VIII. The haul positions of bottom trawl surveys analysed as an index for boarfish abundance. Note the Portuguese Groundfish survey included here was not included in the 2013 assessment.

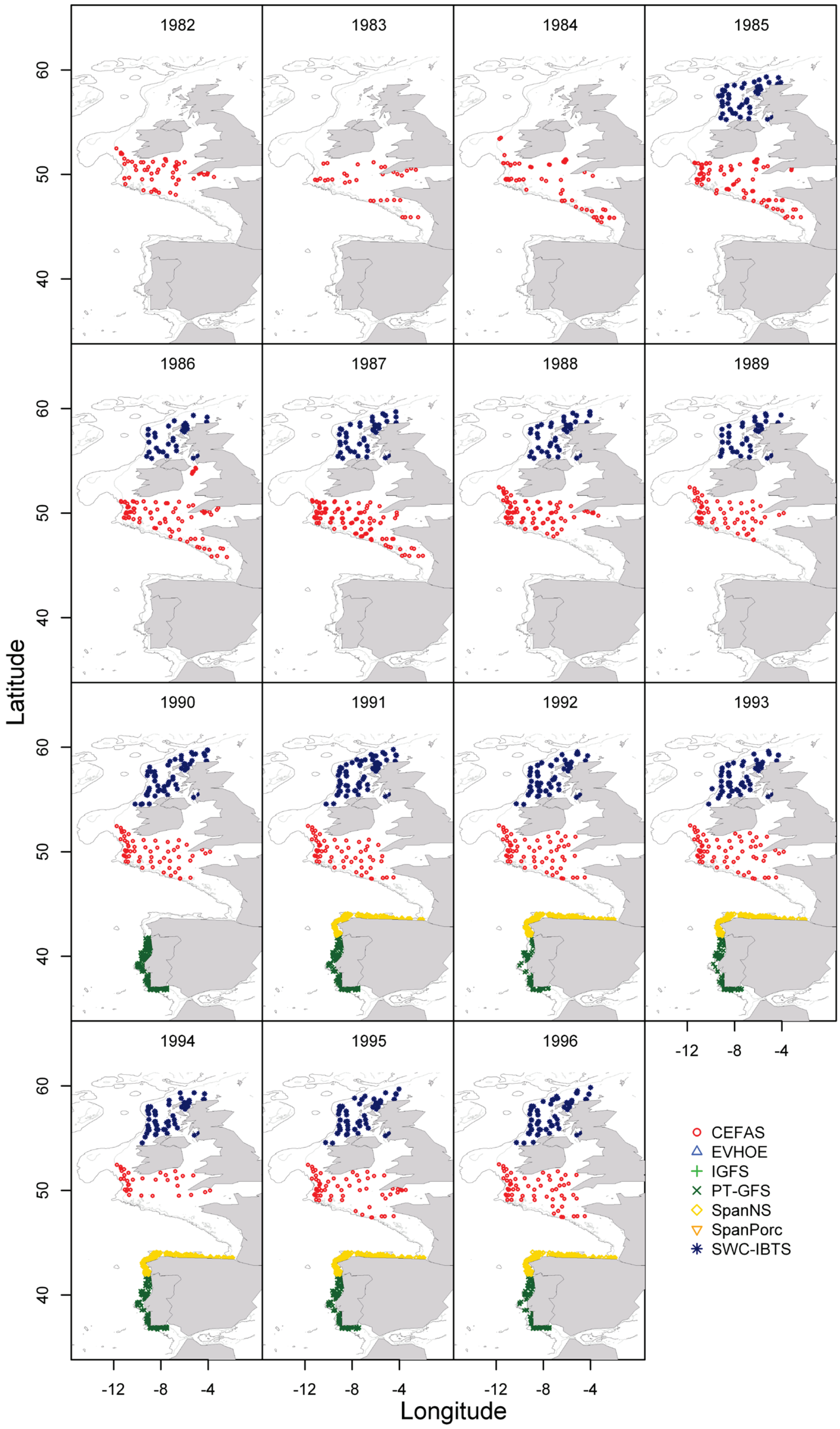

Figure 6.3.2.2a. Boarfish in ICES Subareas VI, VII, VIII. The haul positions of bottom trawl surveys by year analysed as part of the GAM modelling.

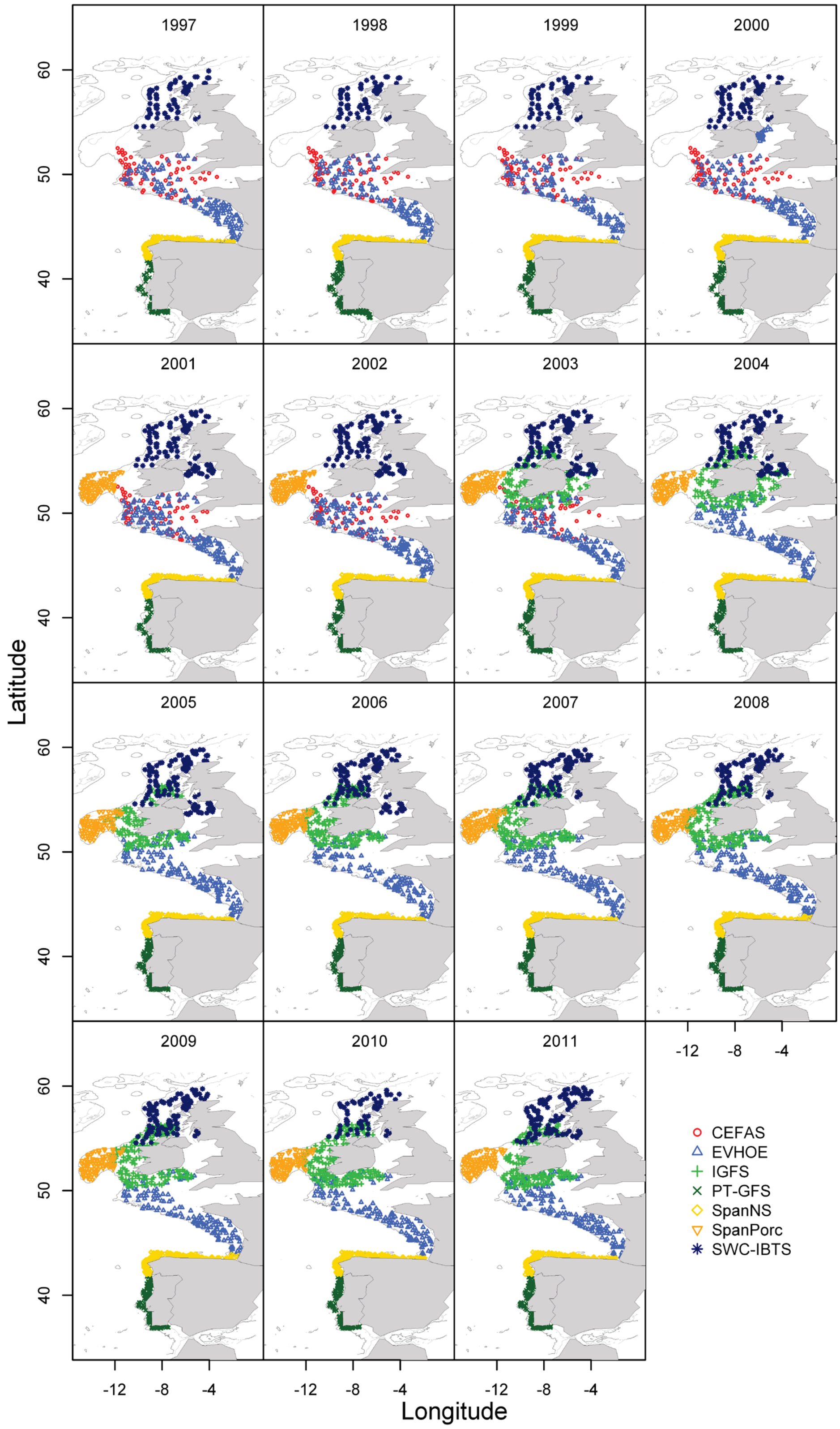

Figure 6.3.2.2b. Boarfish in ICES Subareas VI, VII, VIII. The haul positions of bottom trawl surveys by year analysed as part of the GAM modelling.

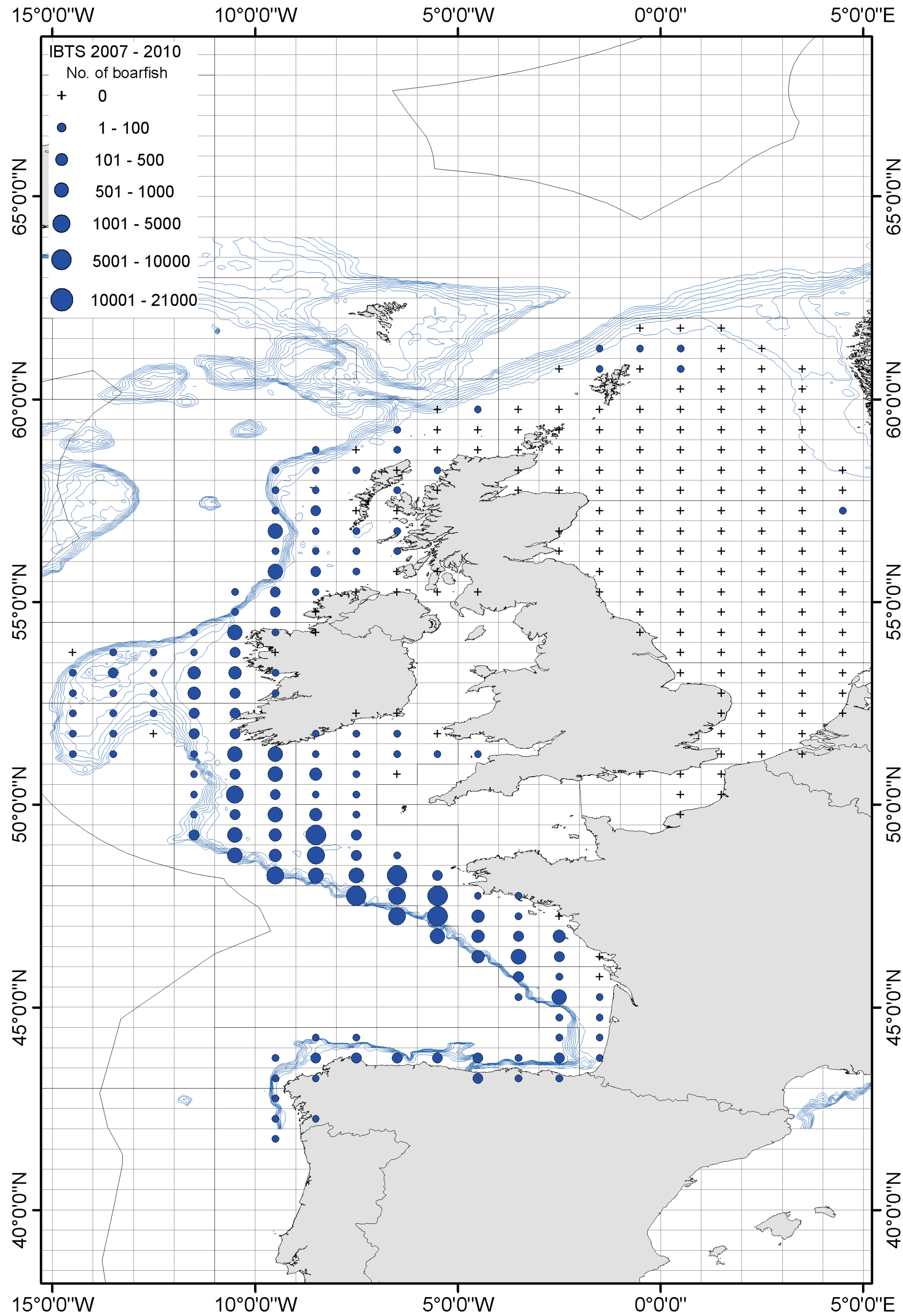

Figure 6.3.2.3. Boarfish in ICES Subareas VI, VII, VIII. Distribution of boarfish in the NE Atlantic showing proposed management area.

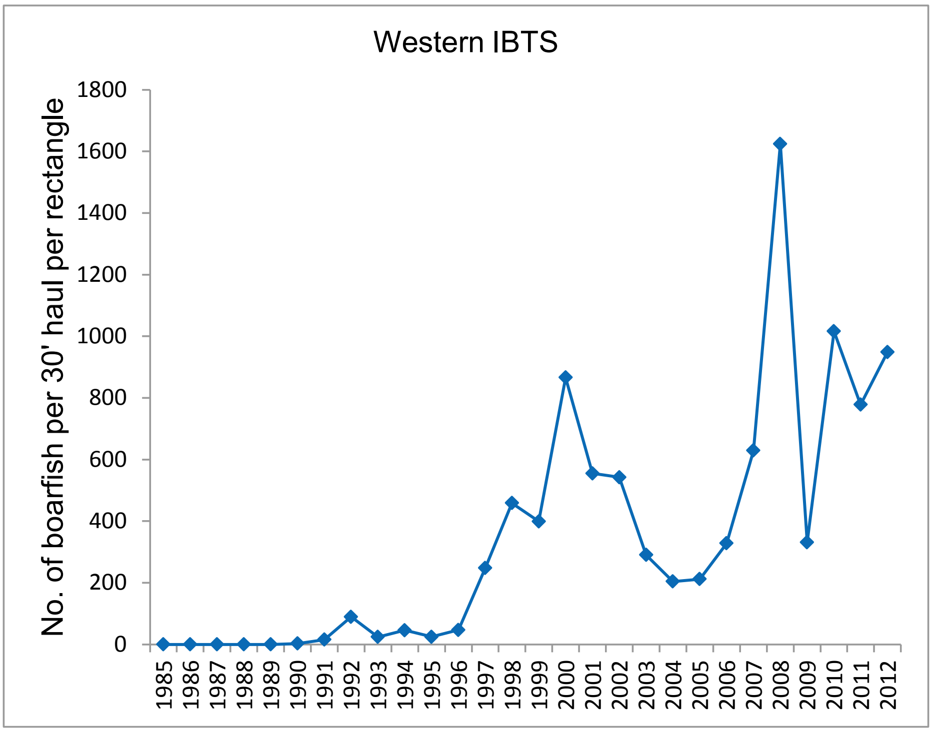

Figure 6.3.2.4. Boarfish in ICES Subareas VI, VII, VIII. CPUE in number per 30 minute haul of boarfish per rectangle in the western IBTS survey 1985 to 2011.

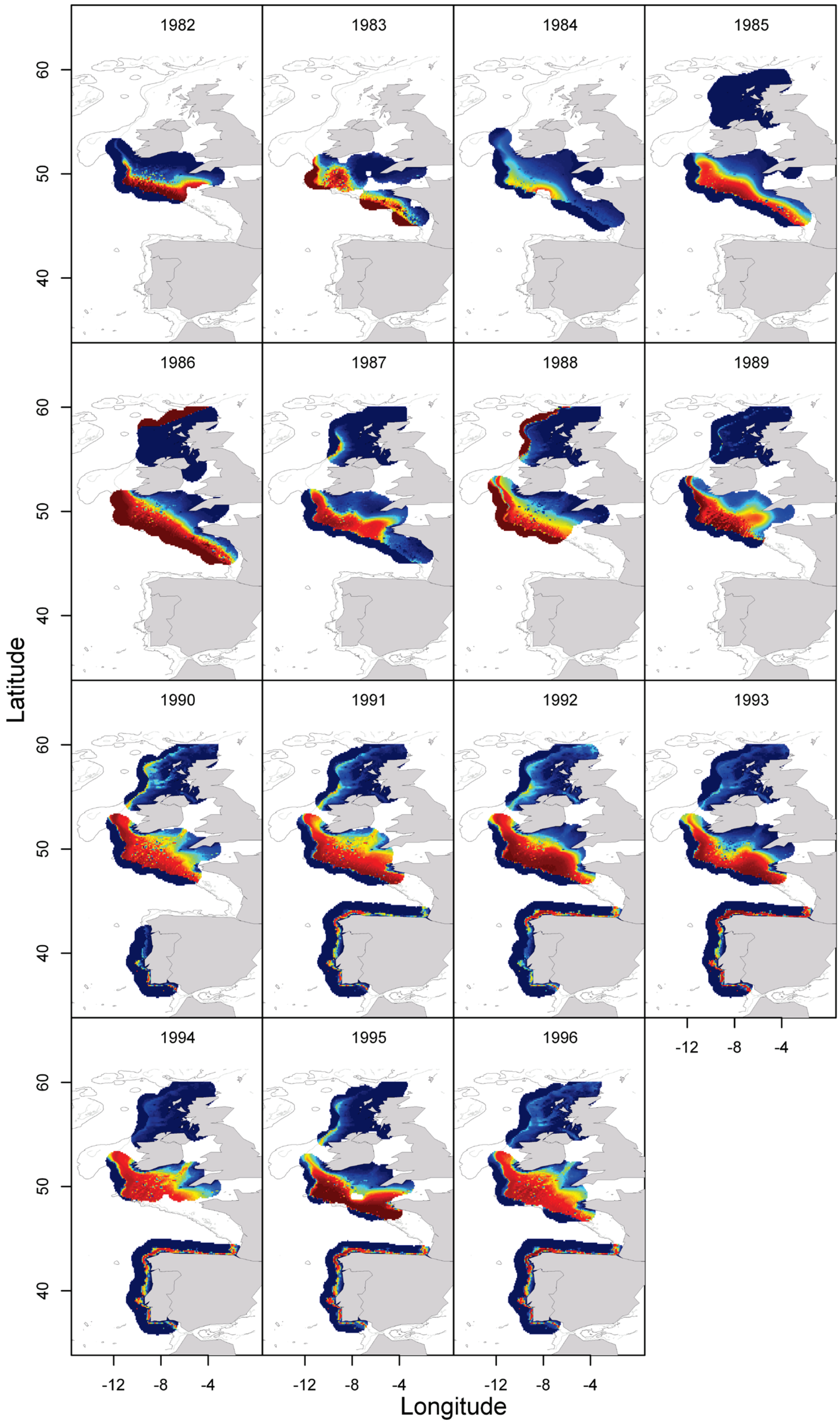

Figure 6.3.2.5a. Boarfish in ICES Subareas VI, VII, VIII. The occurrence GAM of the probability of occurrence of boarfish in a survey area 1982 – 1996. Red indicates definite occurrence and blue indicates absence.

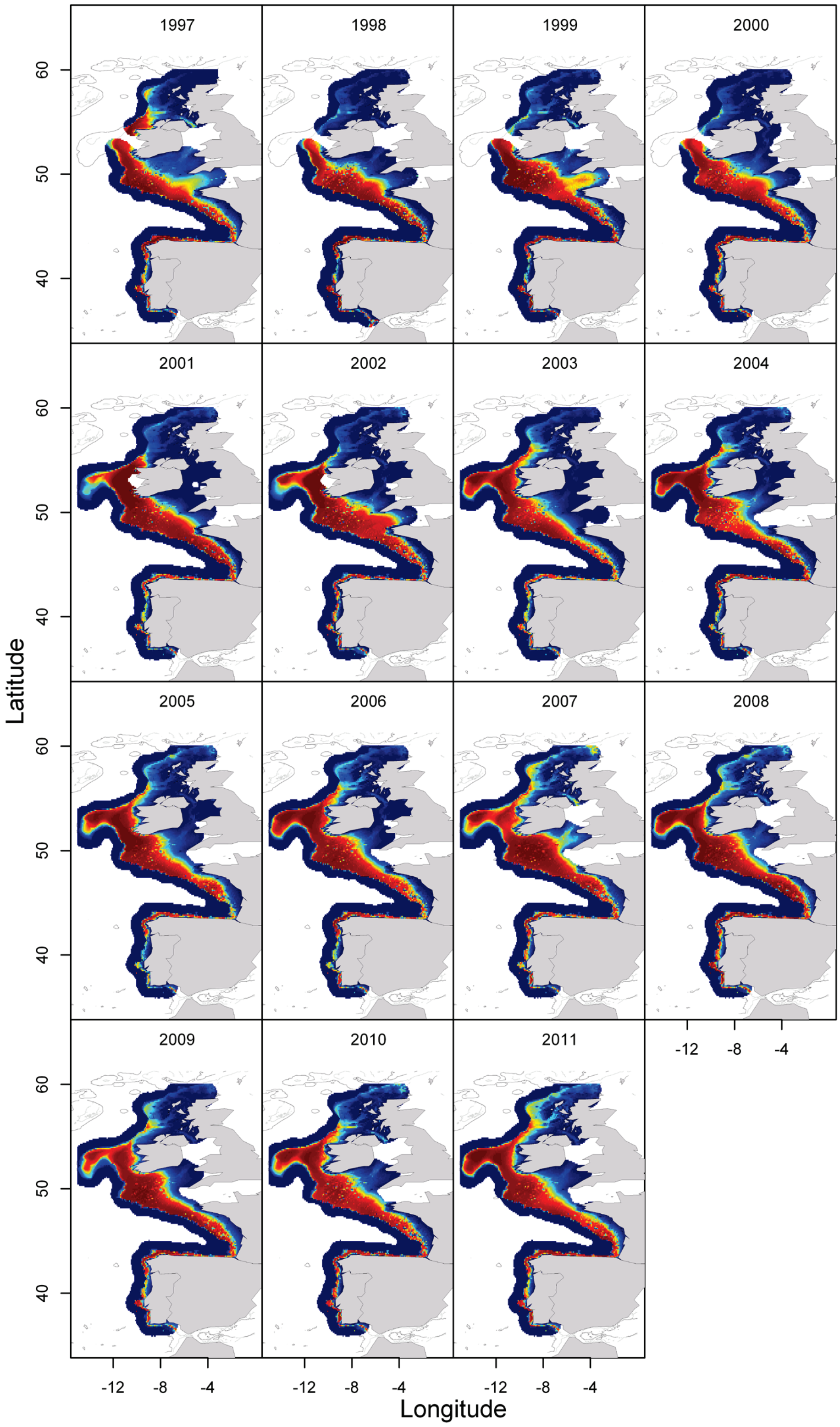

Figure 6.3.2.5b. Boarfish in ICES Subareas VI, VII, VIII. The occurrence GAM of the probability of occurrence of boarfish in a survey area 1997 – 2011. Red indicates definite occurrence and blue indicates absence.

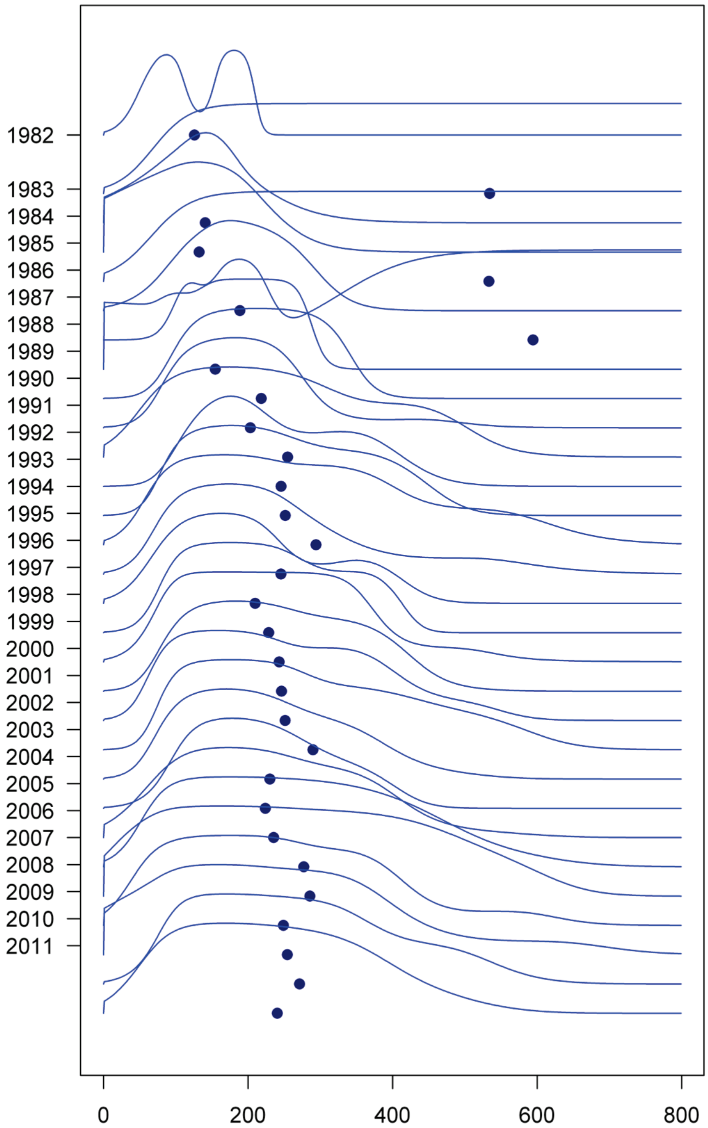

Figure 6.3.2.6. Boarfish in ICES Subareas VI, VII, VIII. The depth distribution profile of boarfish within the IBTS surveys.

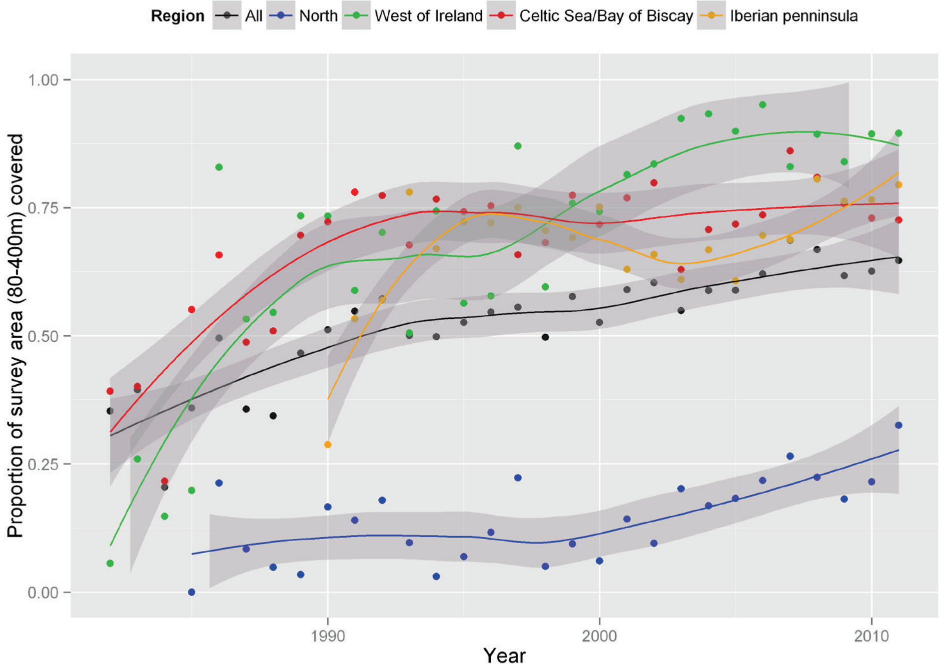

Figure 6.3.2.7. Boarfish in ICES Subareas VI, VII, VIII. The proportion of survey area covered by boarfish per region and per year.

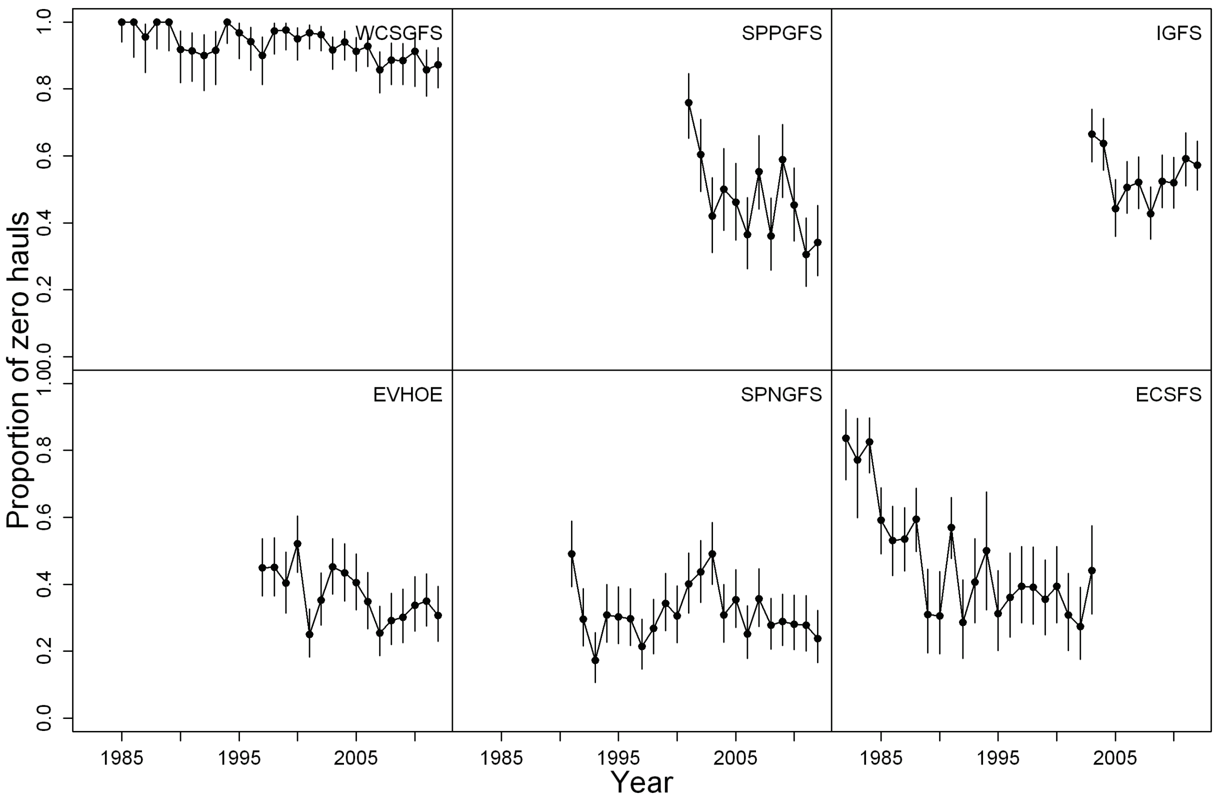

Figure 6.3.2.8. Boarfish in ICES Subareas VI, VII, VIII. The proportion of zero hauls per IBTS survey.

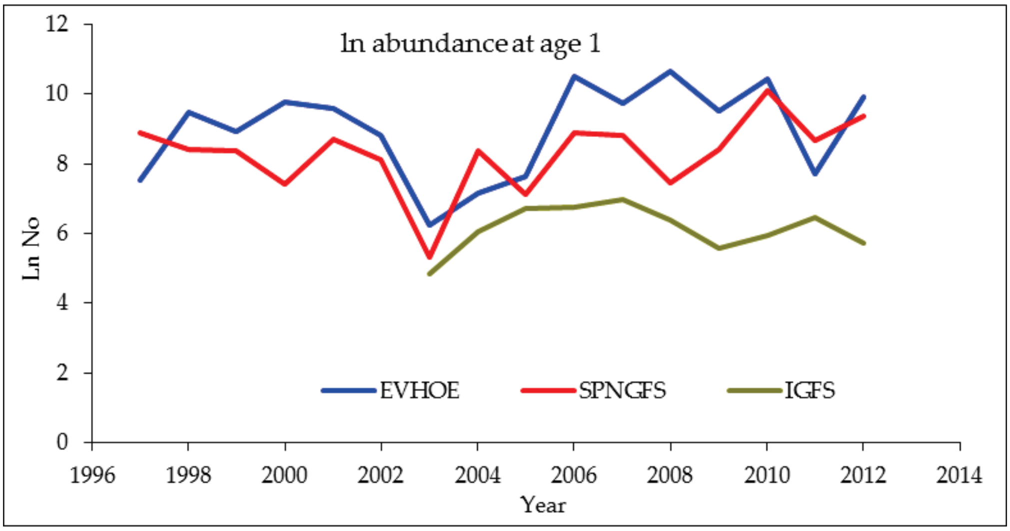

Figure 6.5.1. Boarfish in ICES Subareas VI, VII, VIII. Recruitment-at-age 1, from various IBTS.

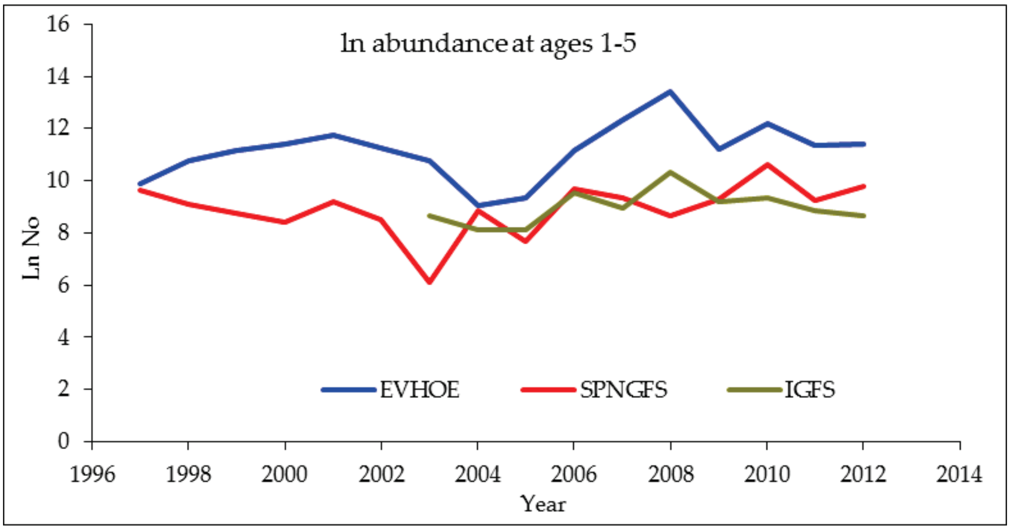

Figure 6.5.2. Boarfish in ICES Subareas VI, VII, VIII. Recruitment-at-ages 1-5, from various IBTS.

Figure 6.6.2.1. Boarfish in ICES Subareas VI, VII, VIII. Abundance-at-age in constituent western IBTS. Yearly mean standardised abundance-at-age.

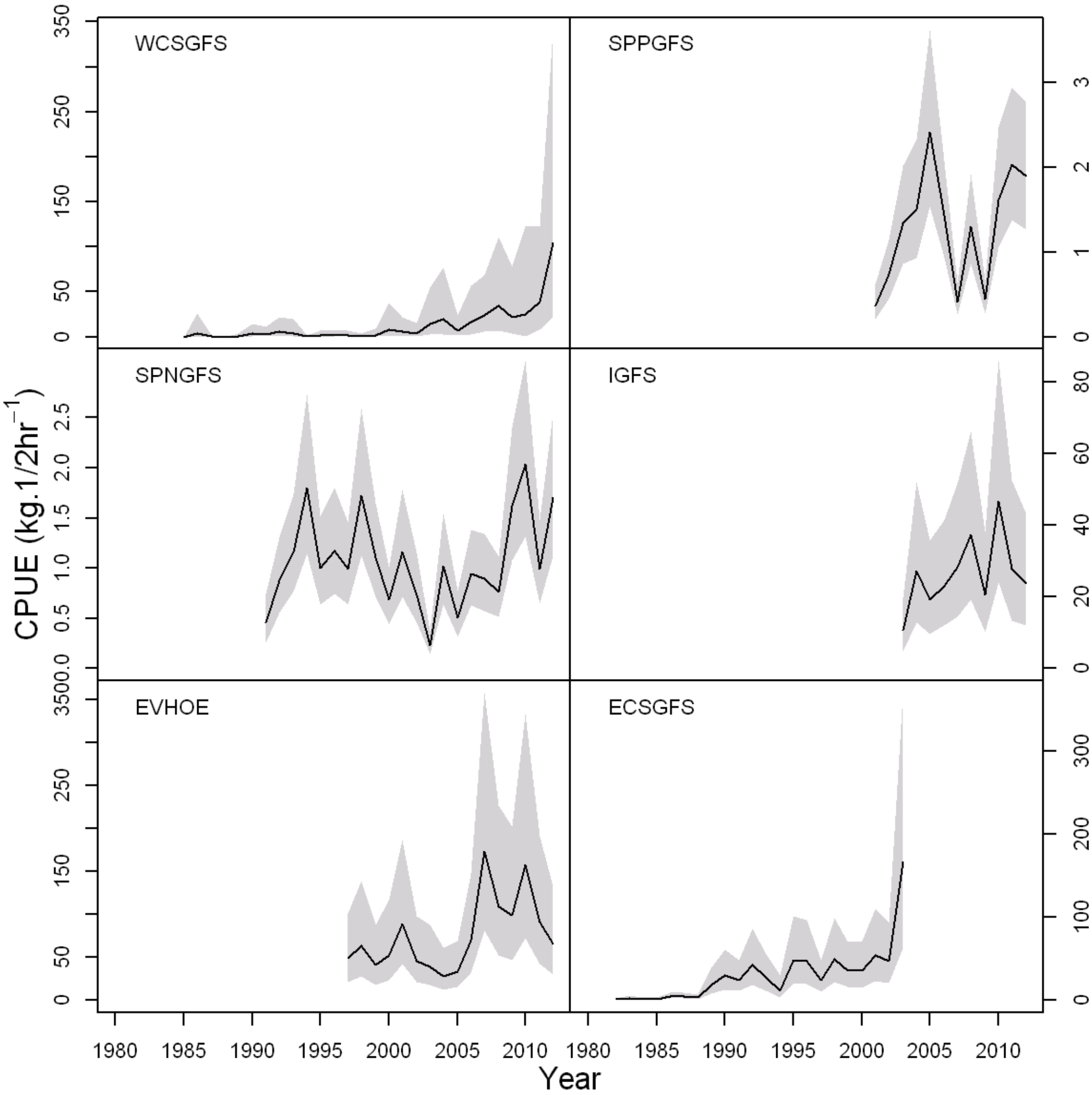

Figure 6.6.2.2. Boarfish in ICES Subareas VI, VII, VIII. Boarfish IBTS survey CPUE fitted delta-lognormal mean (solid line) and 95% credible intervals (grey region).

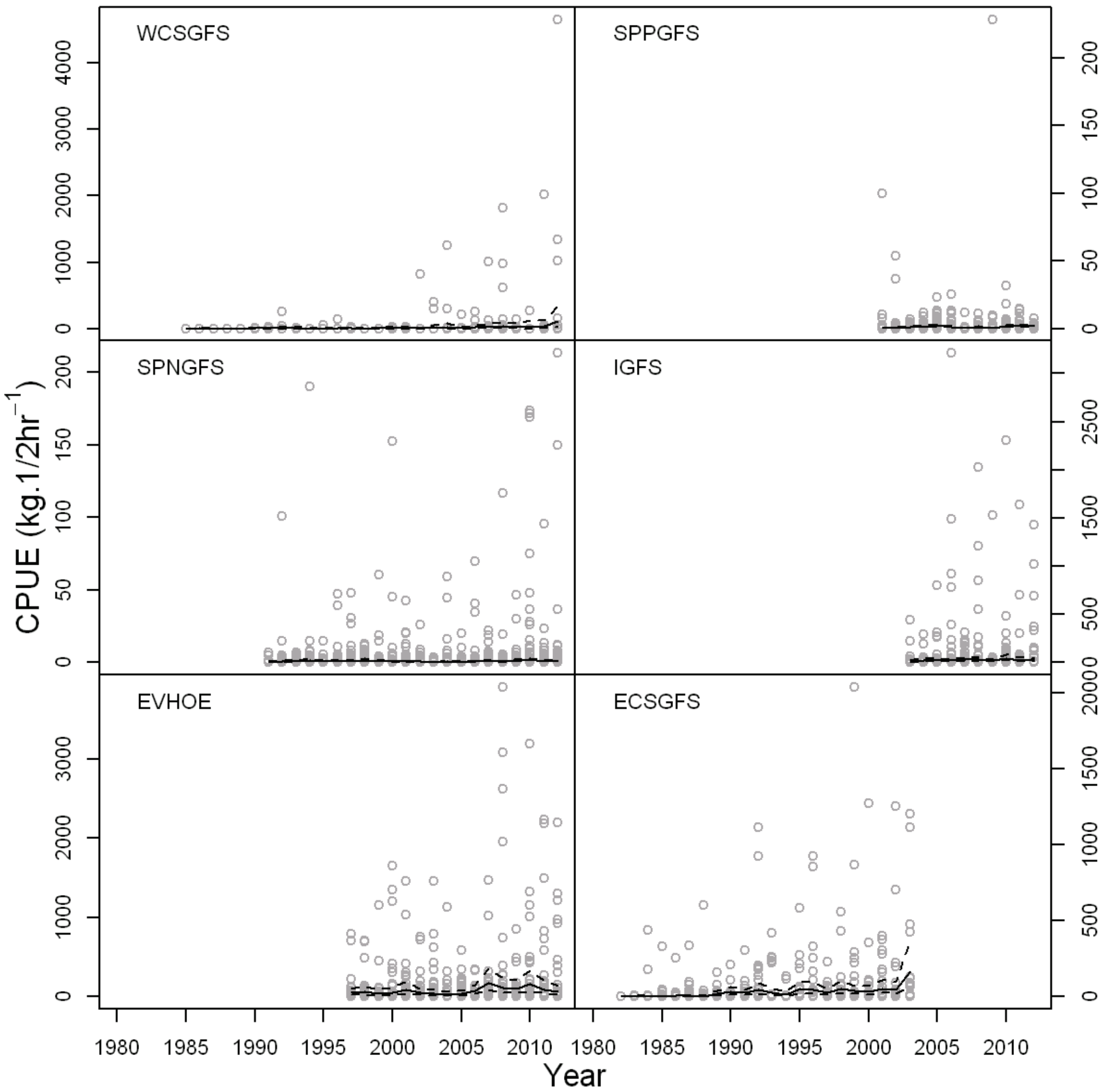

Figure 6.6.2.3. Boarfish in ICES Subareas VI, VII, VIII. Boarfish IBTS survey CPUE data (grey points) and fitted delta-lognormal mean (solid line) and 95% credible intervals (dashed lines).

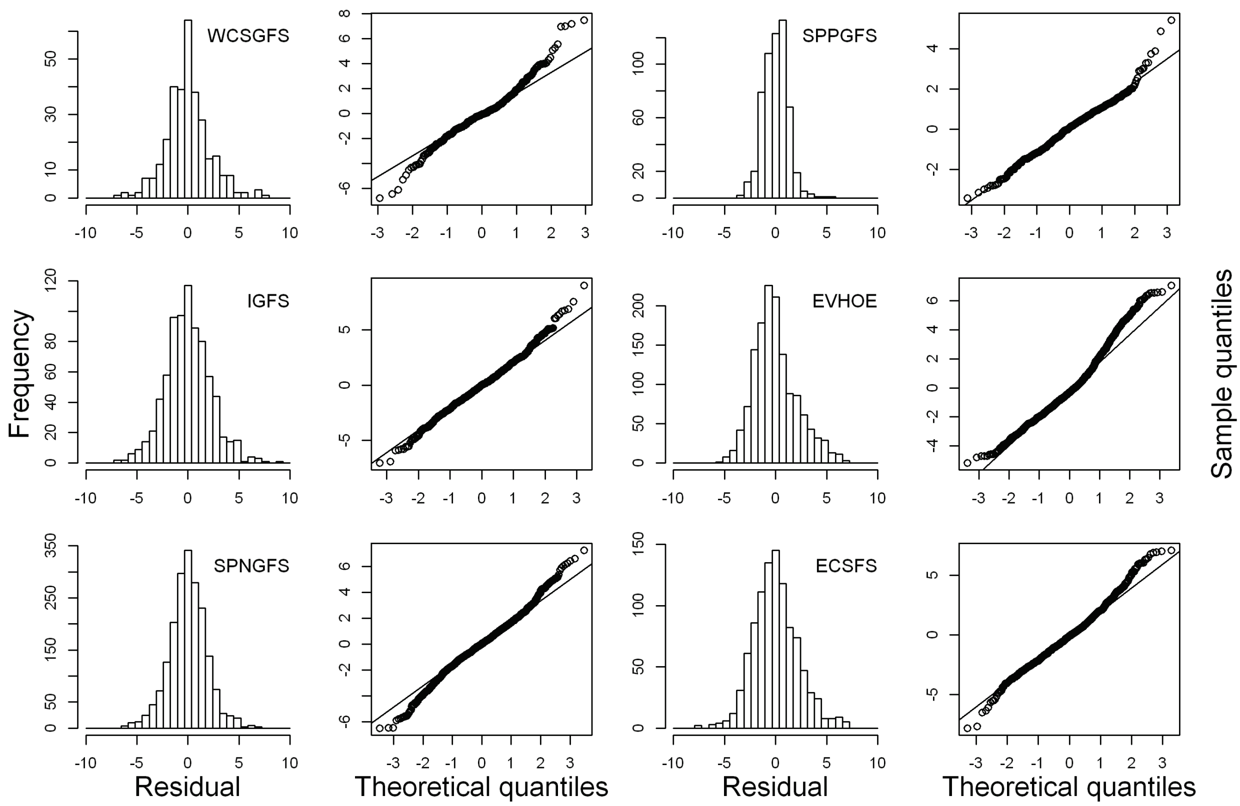

Figure 6.6.2.4. Boarfish in ICES Subareas VI, VII, VIII. Diagnostics from the positive component of the delta-lognormal fits.

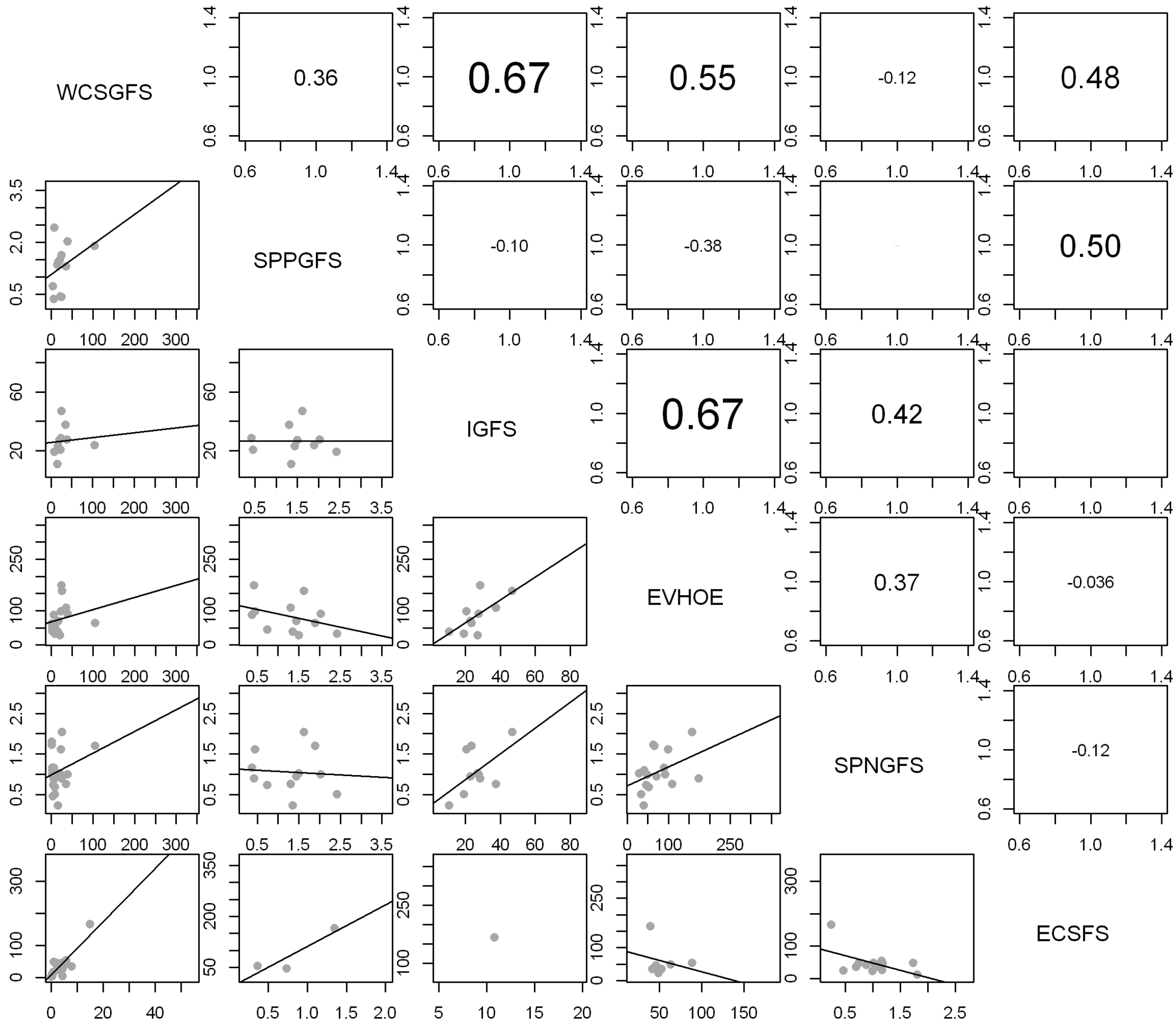

Figure 6.6.2.5. Boarfish in ICES Subareas VI, VII, VIII. Pair-wise correlation between the annual mean survey indices.

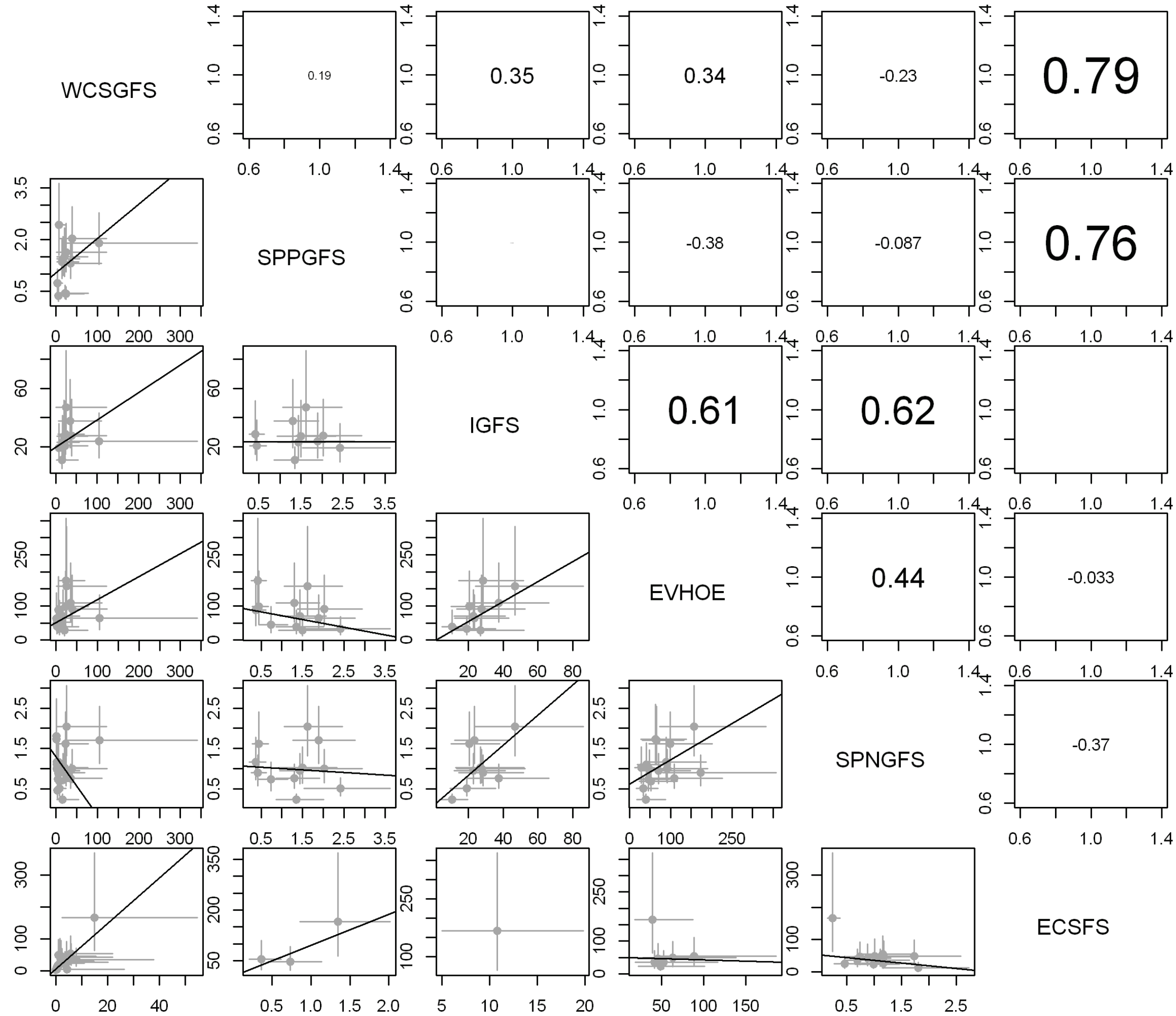

Figure 6.6.2.6. Boarfish in ICES Subareas VI, VII, VIII. Weighted correlation between the annual mean survey indices. Correlations are weighted by the sum of the pair-wise variances.

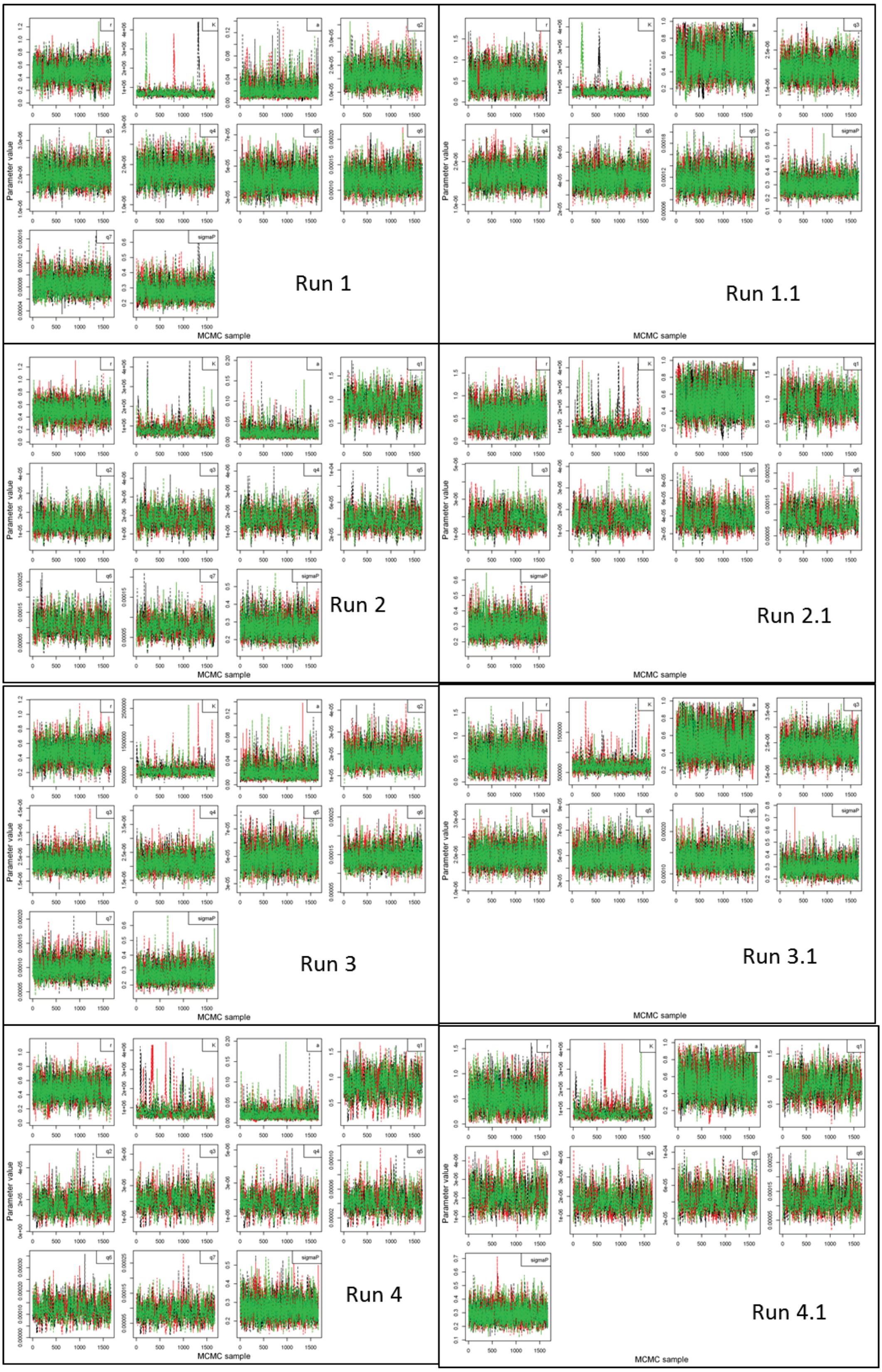

Figure 6.6.5.1. Boarfish in ICES Subareas VI, VII, VIII. Parameters for runs 1-4 and sensitivity runs 1.1, 2.1, 3.1, 4.1 converged with good mixing of the chains.

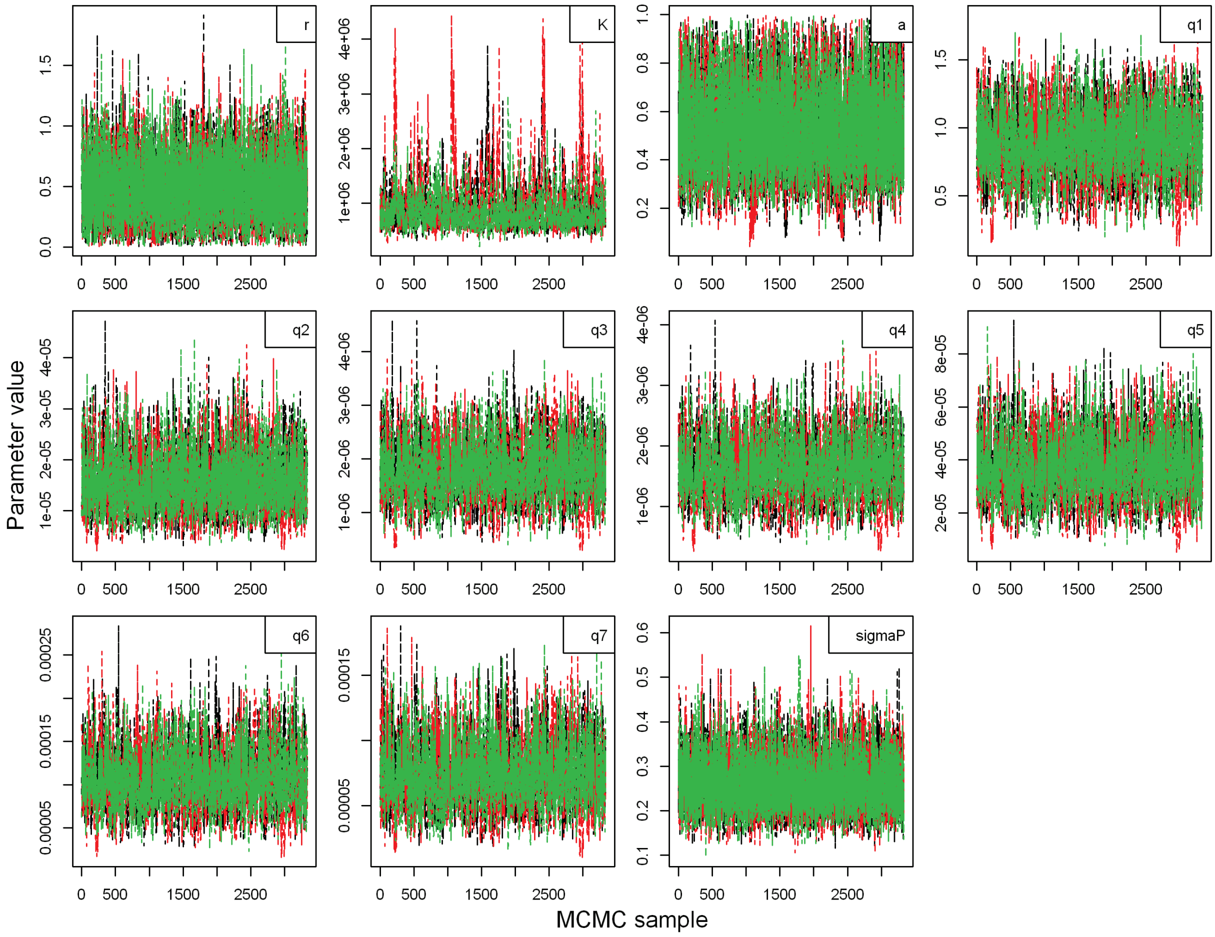

Figure 6.6.5.2. Boarfish in ICES Subareas VI, VII, VIII. Parameters for run 2.2 converged with good mixing of the chains.

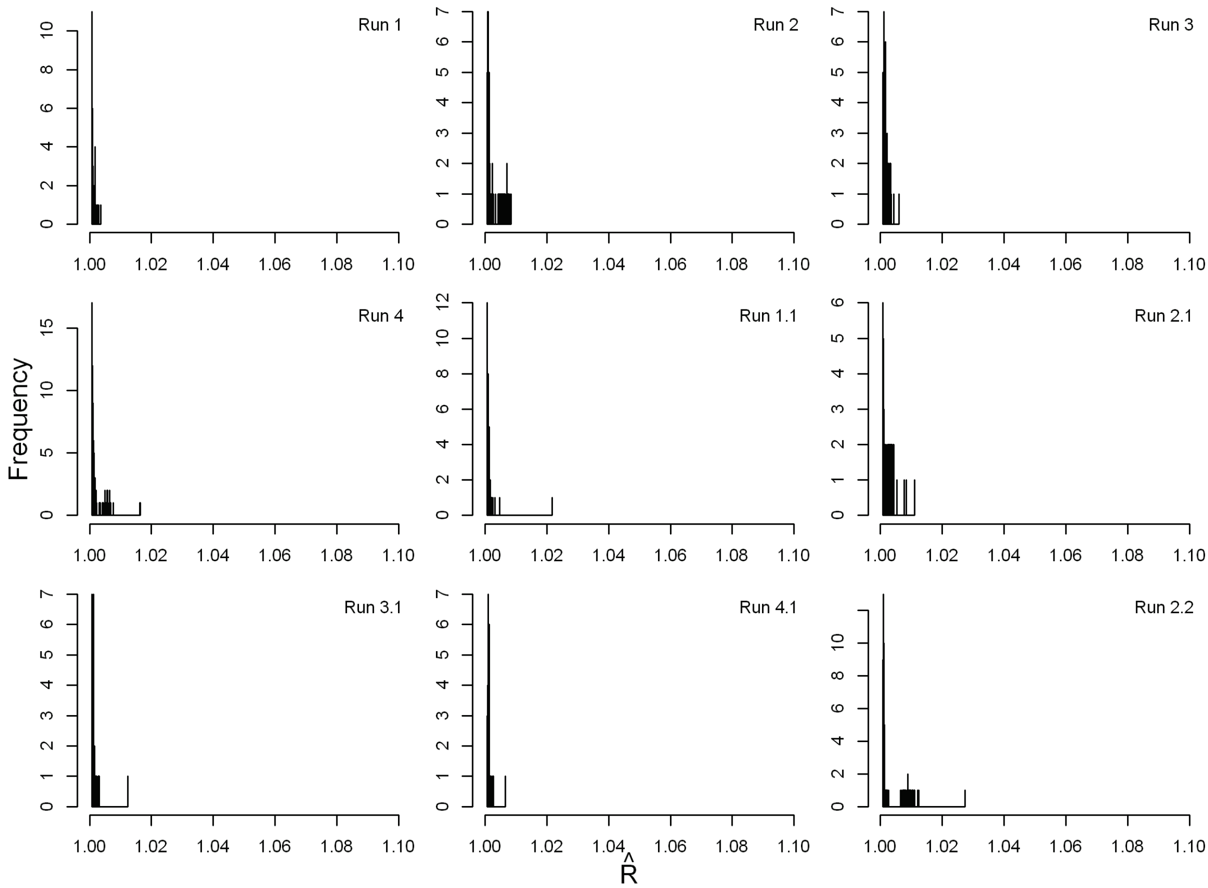

Figure 6.6.5.3. Boarfish in ICES Subareas VI, VII, VIII. Rhat values lower than 1.1 indicating convergence.

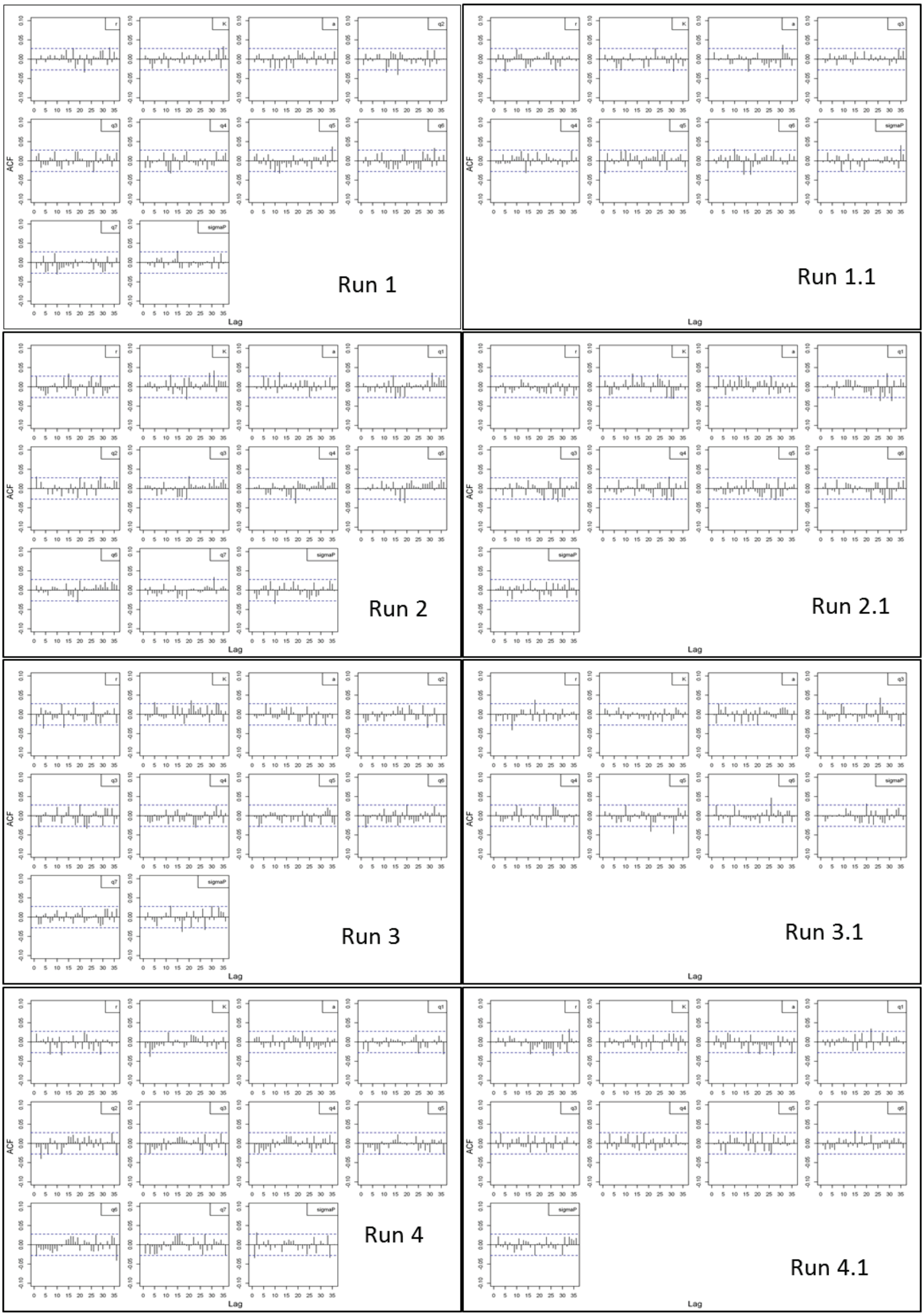

Figure 6.6.5.4. Boarfish in ICES Subareas VI, VII, VIII. MCMC chain autocorrelation for runs 1-4, sensitivity runs 1.1, 2.1, 3.1, 4.1.

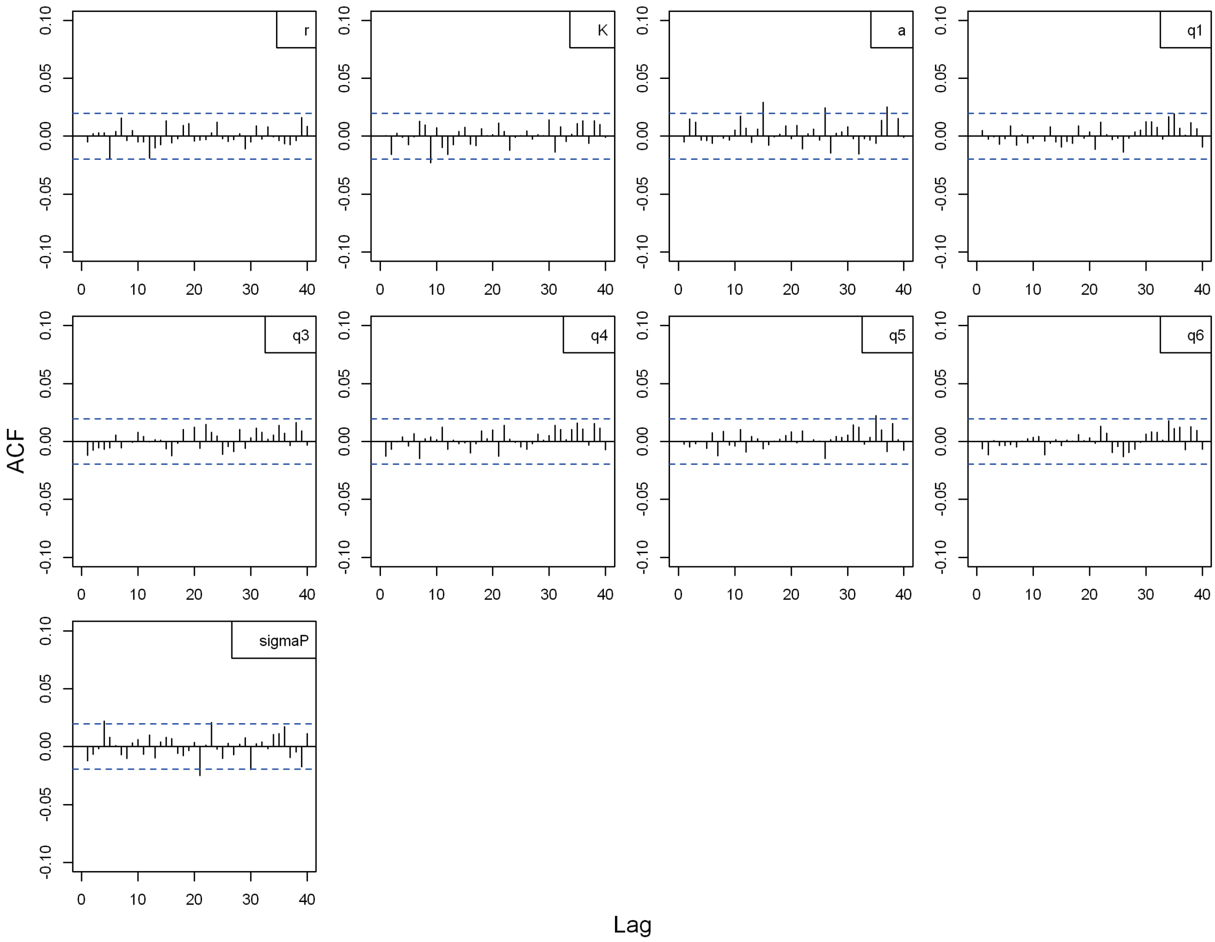

Figure 6.6.5.5. Boarfish in ICES Subareas VI, VII, VIII. MCMC chain autocorrelation for run 2.2.

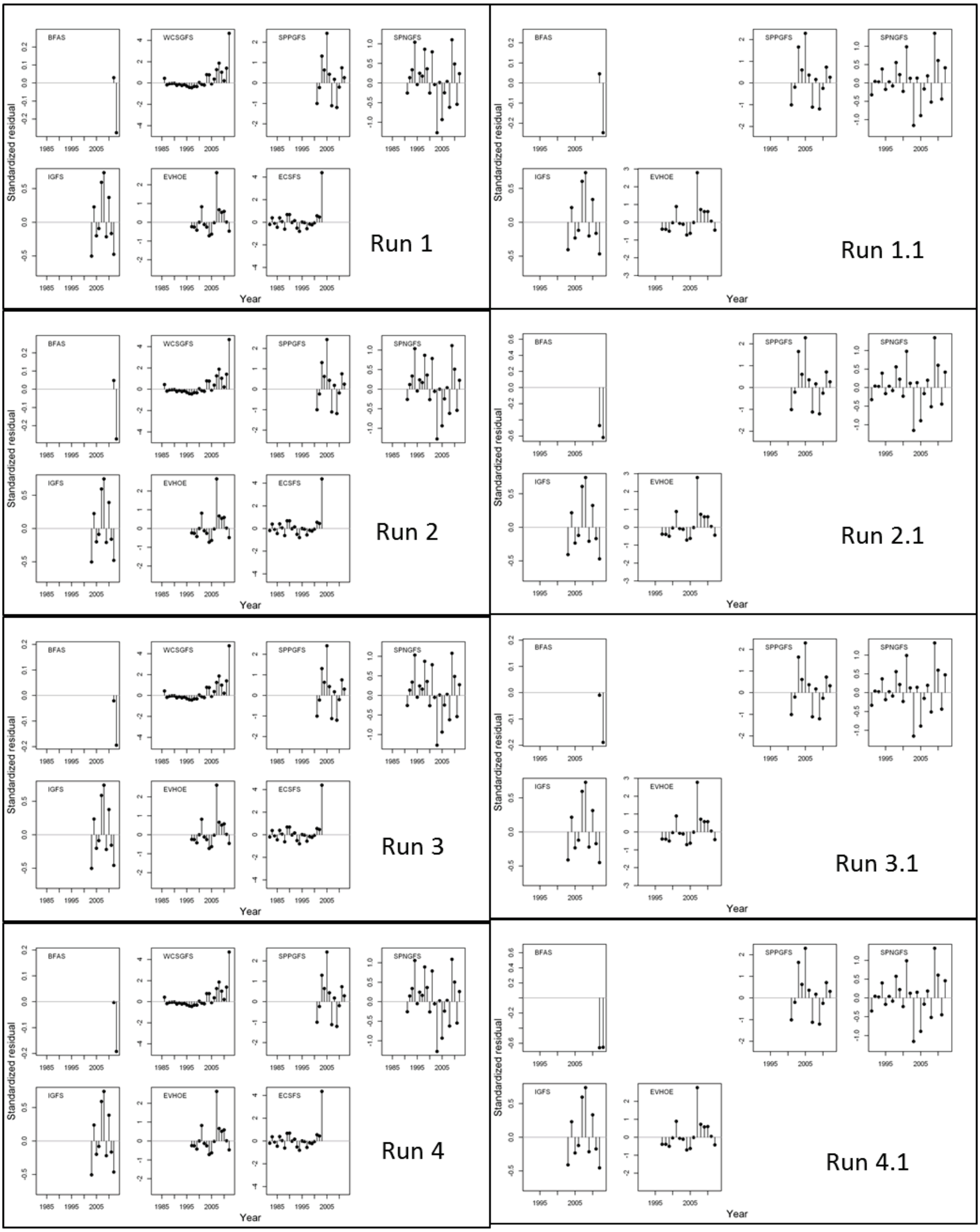

Figure 6.6.5.6. Boarfish in ICES Subareas VI, VII, VIII. Residuals around the model fits for runs 1-4, sensitivity runs 1.1, 2.1, 3.1, 4.1.

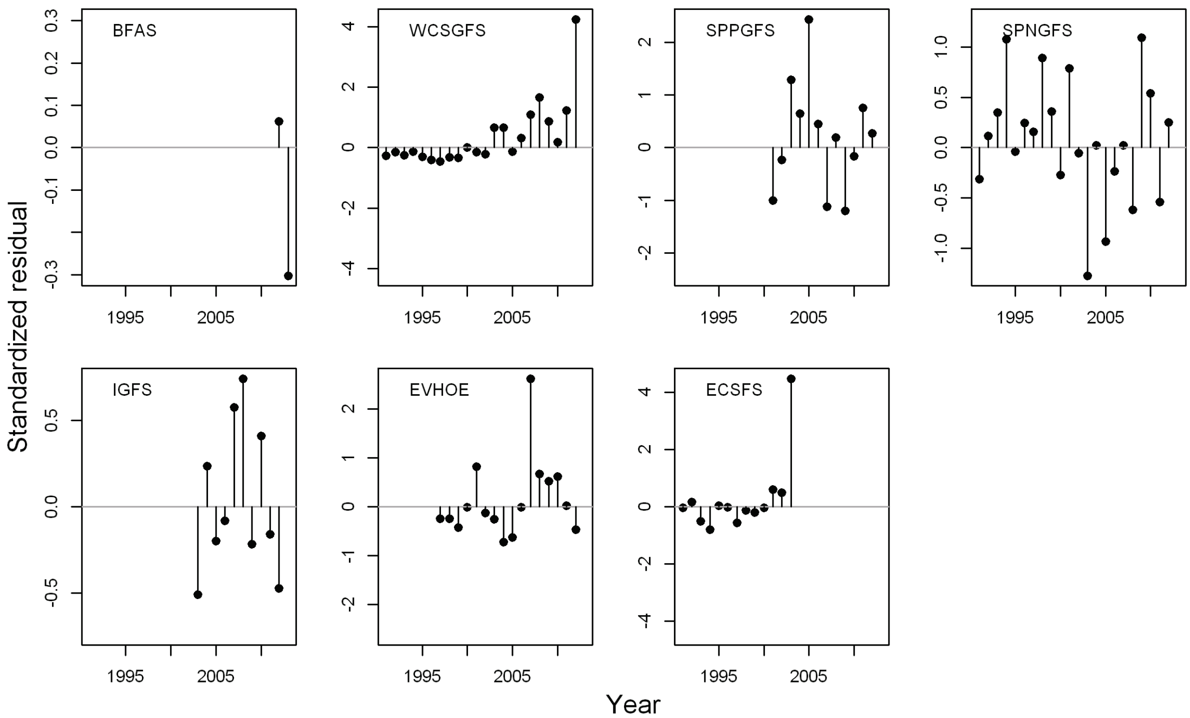

Figure 6.6.5.7. Boarfish in ICES Subareas VI, VII, VIII. Residuals around the model fit for run 2.2.

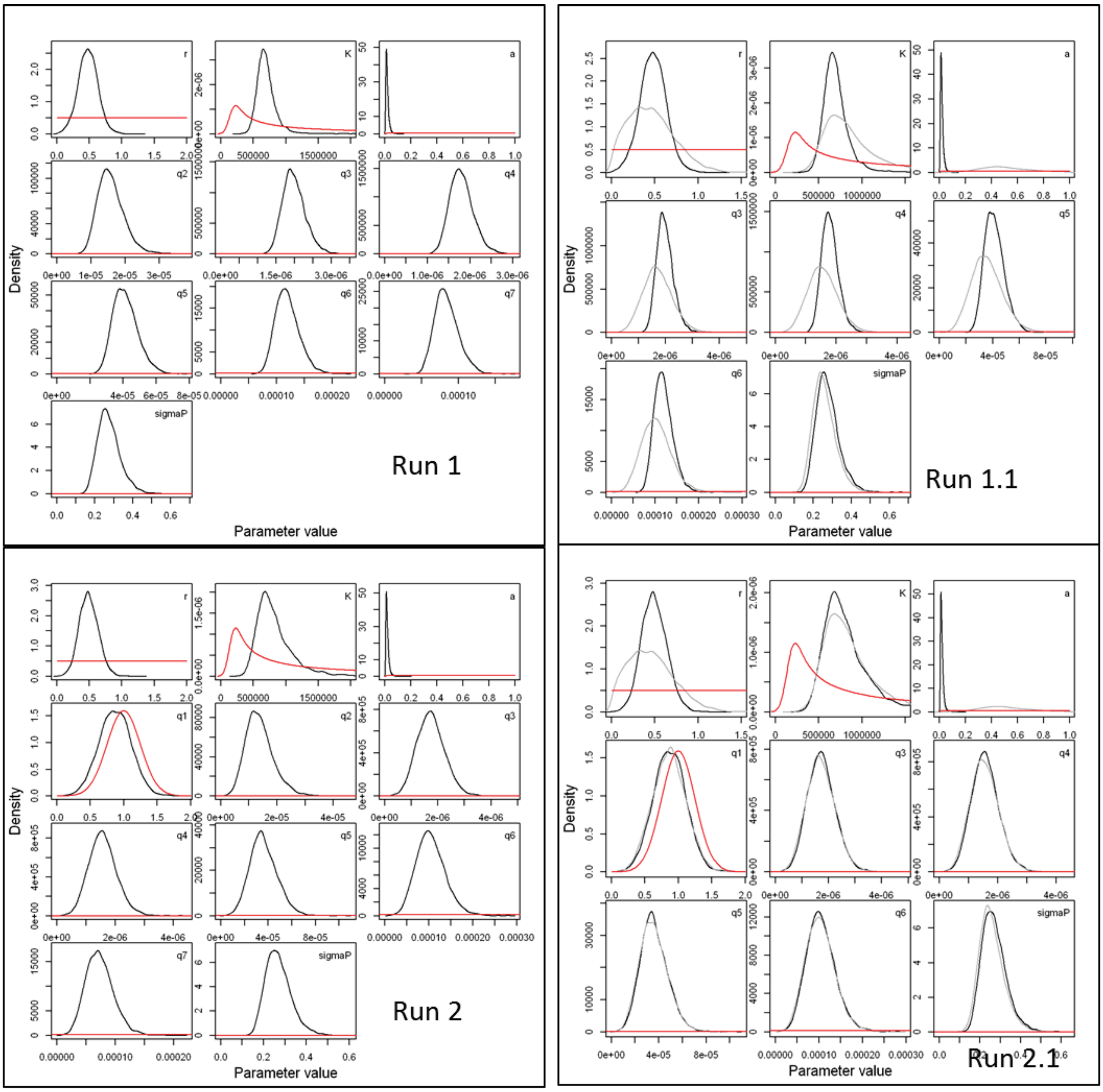

Figure 6.6.5.8. Boarfish in ICES Subareas VI, VII, VIII. prior and posterior distributions of the parameters of the biomass dynamic model. Runs 1, 1.1, 2 and 2.1.

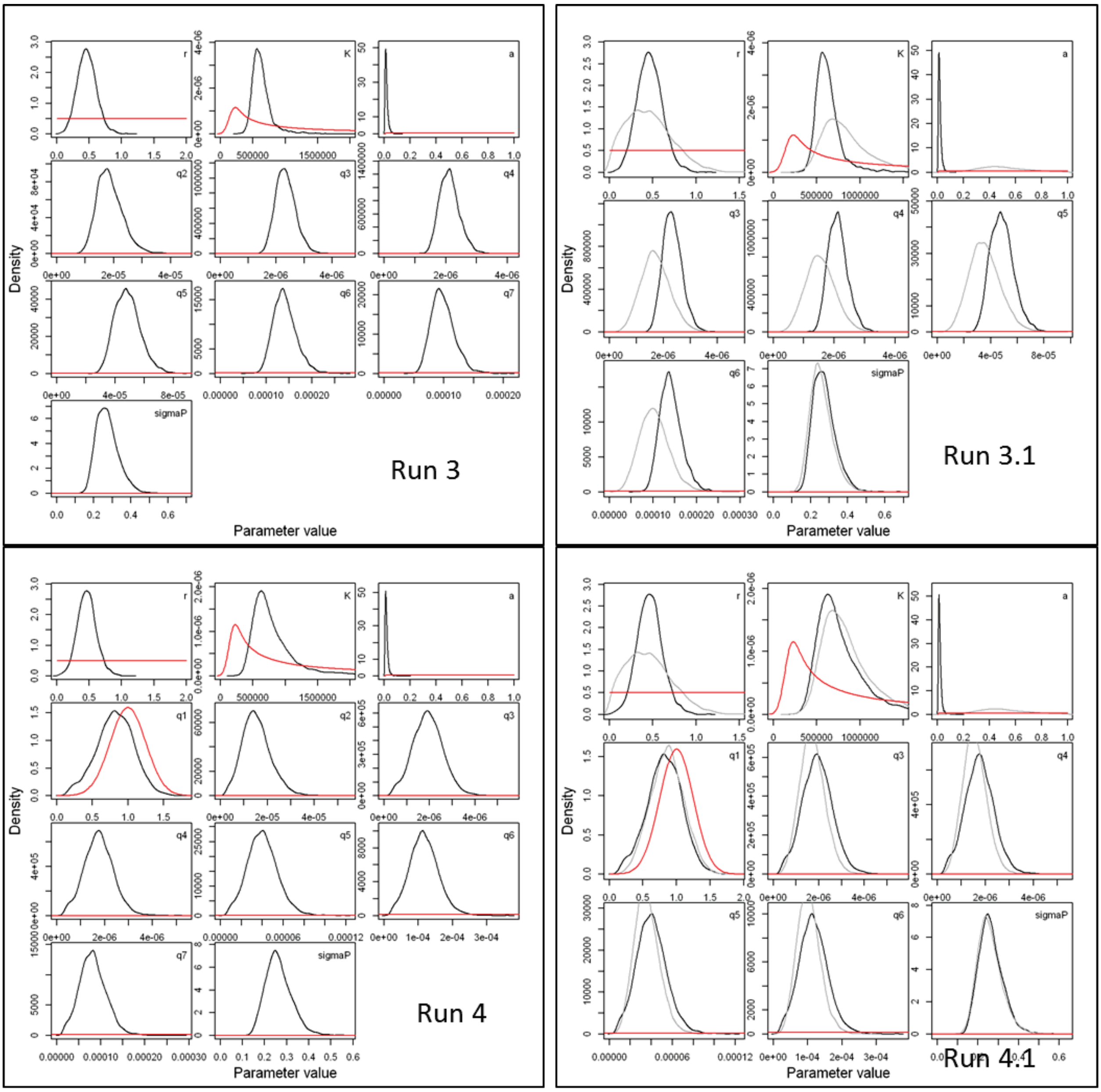

Figure 6.6.5.9. Boarfish in ICES Subareas VI, VII, VIII. prior and posterior distributions of the parameters of the biomass dynamic model. Runs 3, 3.1, 4 and 4.1.

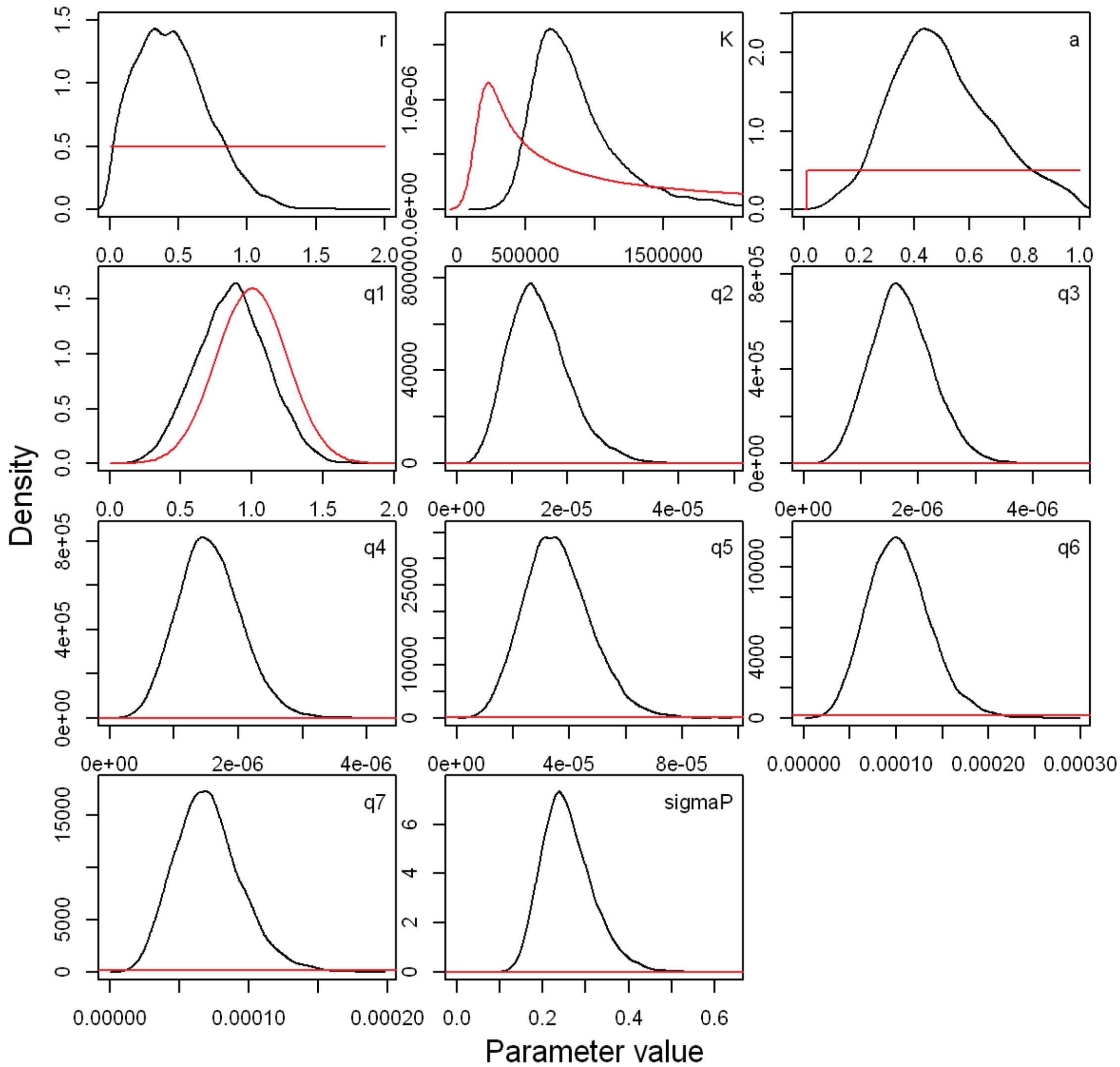

Figure 6.6.5.10. Boarfish in ICES Subareas VI, VII, VIII. prior and posterior distributions of the parameters of the biomass dynamic model. Run 2.2.

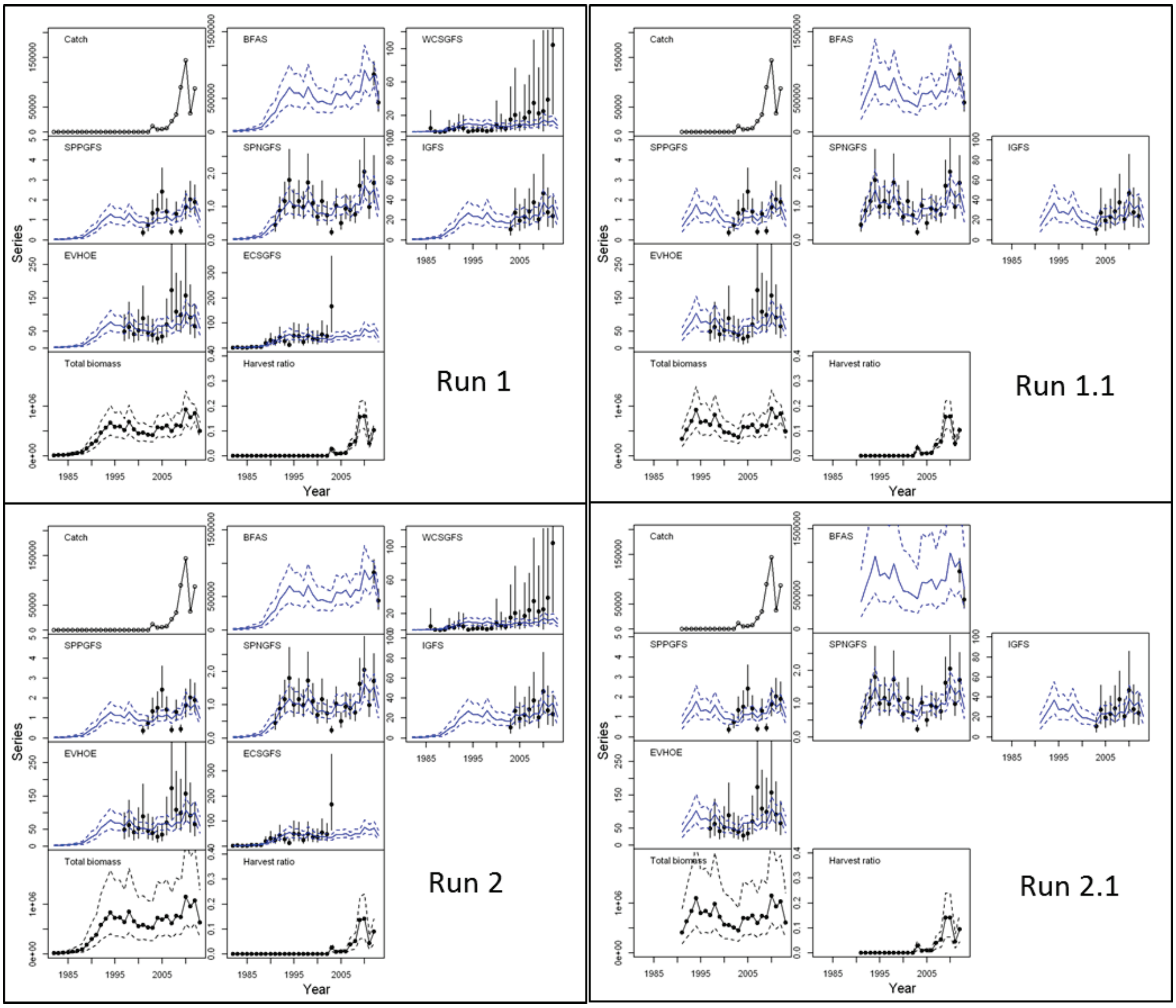

Figure 6.6.5.11. Boarfish in ICES Subareas VI, VII, VIII. Trajectories of observed and expected indices for runs 1, 1.1, 2 and 2.1. The stock size over time and a harvest ratio (total catch divided by estimated biomass) are also shown.

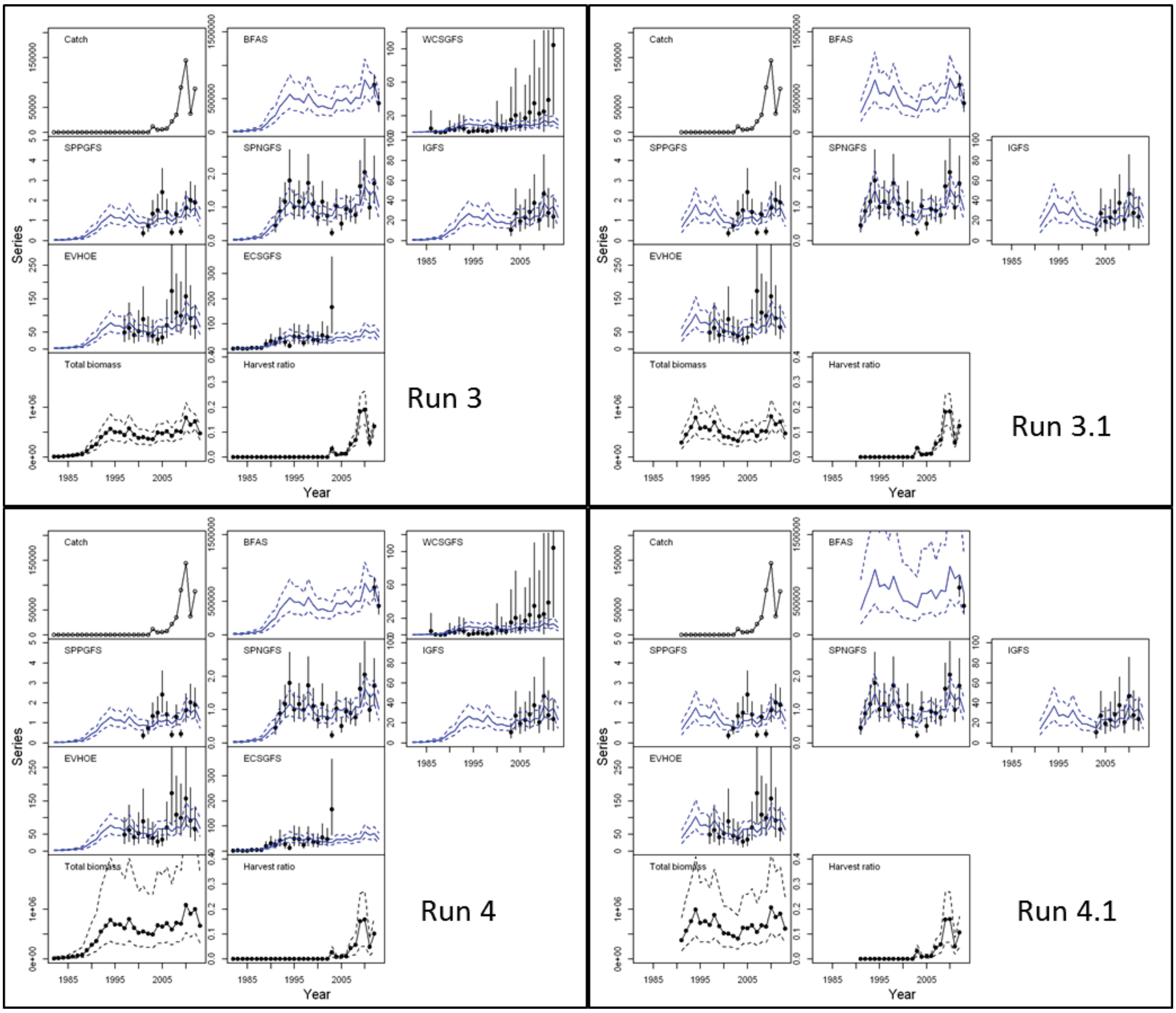

Figure 6.6.5.12. Boarfish in ICES Subareas VI, VII, VIII. Trajectories of observed and expected indices for runs 3, 3.1, 4 and 4.1. The stock size over time and a harvest ratio (total catch divided by estimated biomass) are also shown.

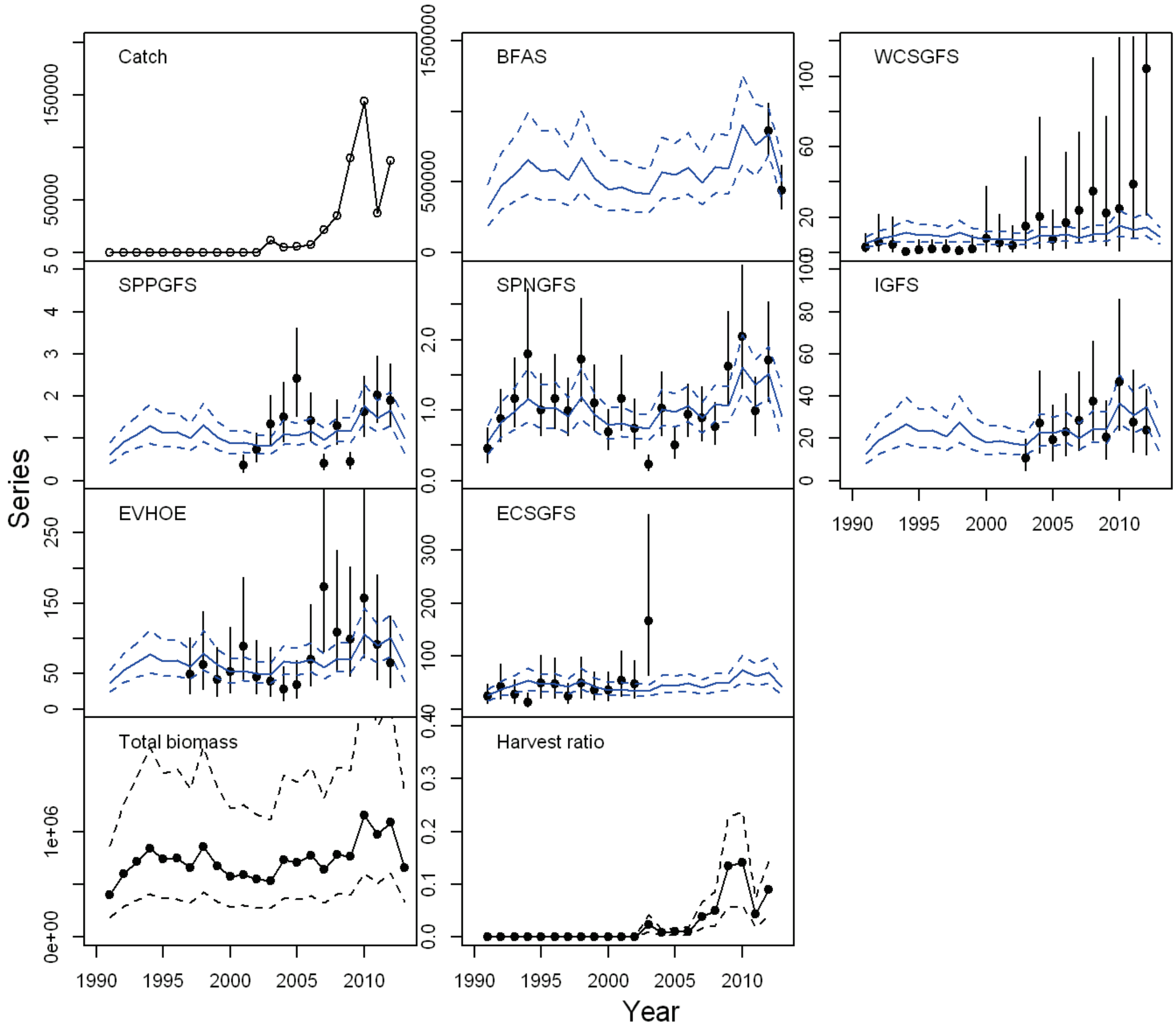

Figure 6.6.5.13. Boarfish in ICES Subareas VI, VII, VIII. Trajectories of observed and expected indices for run 2.2. The stock size over time and a harvest ratio (total catch divided by estimated biomass) are also shown.

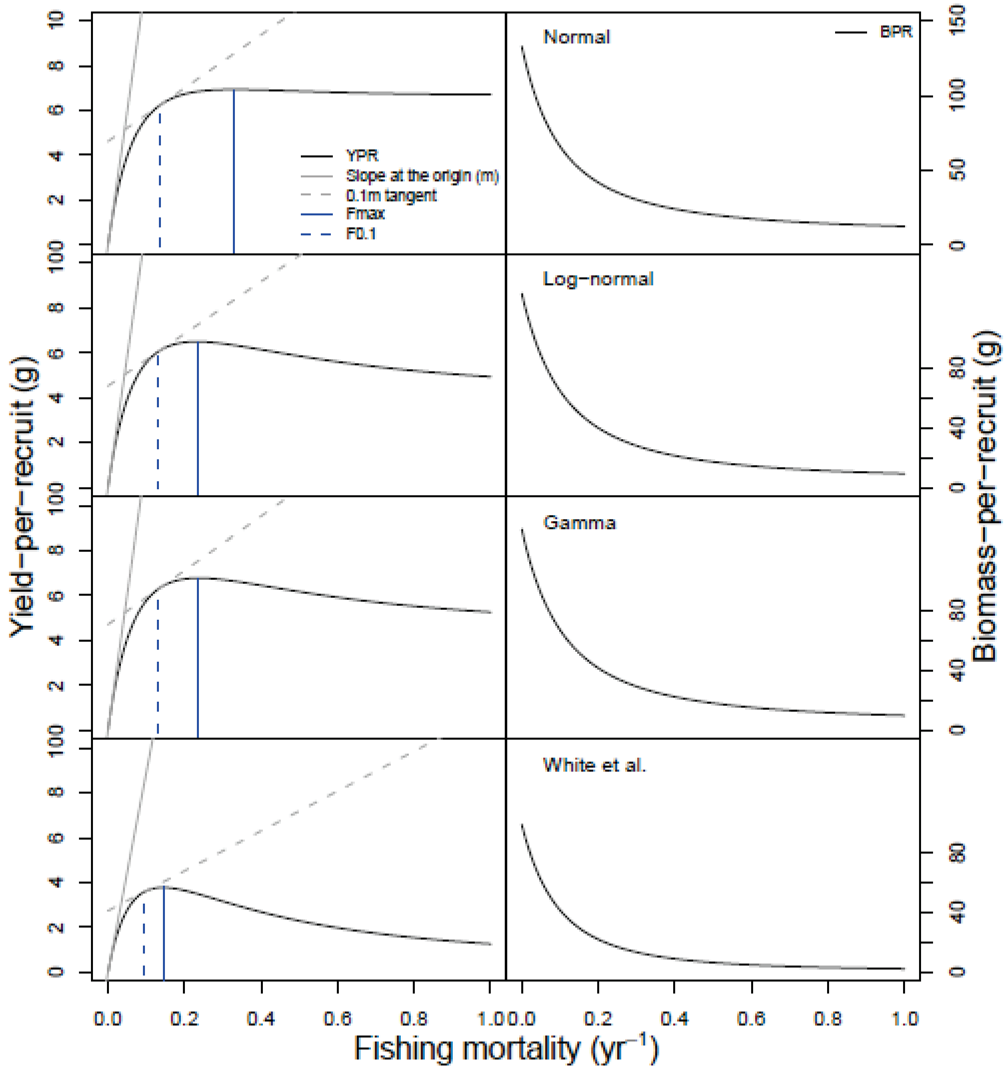

Figure 6.7.1.1. Boarfish in ICES Subareas VI, VII, VIII. Results of exploratory yield per recruit analysis. Beverton and Holt model applied to various fits of the VBGF and for comparison with the VBGF parameters provided by White *et al.* 2011.

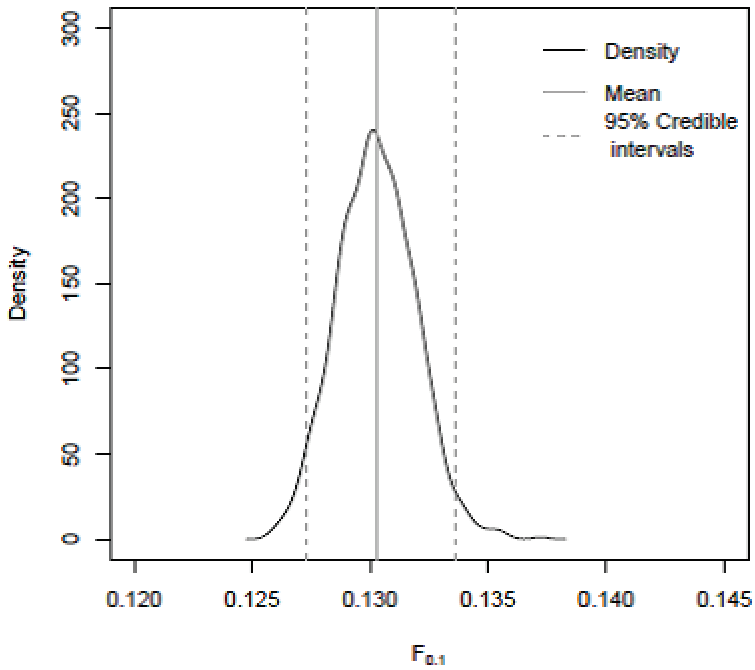

Figure 6.7.1.2. Boarfish in ICES Subareas VI, VII, VIII. Sensitivity of estimation of $F_{0.1}$.

7 Norwegian Spring Spawning Herring

7.1 ICES advice in 2012

Based on the most recent estimates of fishing mortality in 2011, ICES stated that the stock is being harvested below F_{MSY} but above the management target. The SSB is declining but still above B_{pa} and MSY $B_{trigger}$ in 2012. Presently three large year classes (2002, 2003, and 2004) dominate the stock. All year classes from 2005 onwards have been small, generally less than half the geometric mean.

A long term management plan, agreed by the EU, Faroe Islands, Iceland, Norway and Russia, is operational since 1999. ICES has evaluated the plan and concludes that it is in accordance with the precautionary approach. The management plan implies maximum catches of 619 000 t in 2013.

7.2 Management in 2012 and 2013

EU, Faroe Islands, Iceland, Norway, and Russia agreed in 1996 to implement a long-term management plan for Norwegian spring-spawning herring. The management plan was part of the international agreement on total quota setting and sharing of the quota during the years 1997–2002. In the years 2003–2006 there was no agreement between the Coastal States regarding the allocation of the quota. In this period quotas were set unilaterally and in some countries quota were raised during the year. In the years 2007-2012 the Coastal States have agreed to set a TAC in accordance with the management plan. In 2013, Faroe Islands have withdrawn from the Coastal States agreement on the allocation of the quota.

The management plan in use contains the following elements:

- Every effort shall be made to maintain a level of Spawning Stock Biomass (SSB) greater than the critical level (B_{lim}) of 2 500 000 t.
- For 2012 and subsequent years, the Parties agreed to restrict their fishing on the basis of a TAC consistent with a fishing mortality rate of less than 0.125 for appropriate age groups as defined by ICES, unless future scientific advice requires modification of this fishing mortality rate.
- Should the SSB fall below a reference point of 5 000 000 t (B_{pa}), the fishing mortality rate, referred under Paragraph 2, shall be adapted in the light of scientific estimates of the conditions then prevailing to ensure a safe and rapid recovery of the SSB to a level in excess of 5 000 000 t. The basis for such adaptation should be at least a linear reduction in the fishing mortality rate from 0.125 at B_{pa} (5 000 000 t) to 0.05 at B_{lim} (2 500 000 t).
- The Parties shall, as appropriate, review and revise these management measures and strategies on the basis of any new advice provided by ICES.

Each Party may transfer unutilised quantities of up to 10% of the quota allocated to the Party for 2013 to the quota allocated to that Party for 2014. Such transfer shall be an addition to the quota allocated to that Party for 2014. Each Party may also authorise fishing by its vessels of up to 10% beyond the quota allocated. All quantities fished beyond the allocated quota for 2013 shall be deducted from the Party's allocation for 2014. Further arrangements, including arrangements for access and other conditions for fishing in the respective zones of fisheries jurisdiction of the Parties, are regulated by bilateral arrangements.

The agreed TAC for 2012[1] was 833 000 tonnes. The agreed shares of the Parties are 54 228 tonnes for the European Union, 42 983 tonnes for Faroe Islands, 120 868 tonnes for Iceland, 508 130 tonnes for Norway and 106 791 tonnes for the Russian Federation.

The agreed TAC for 2013[2] was 619 000 tonnes. The agreed shares of the Parties (excluding the Faroe Islands) are 40 297 tonnes for the European Community, 89 817 tonnes for Iceland, 377 590 tonnes for Norway and 79 356 tonnes for the Russian Federation. In addition the Parties agreed to set aside a quantity of 31 940 tonnes for the Faroe Islands based on the sharing arrangement agreed between the Parties in Oslo 18 January 2007.

Unilaterally, the Faroe Islands has decided[3] to fix a national catch ceiling at 17 per cent of the TAC of 619 000 tonnes as advised by ICES for 2013. This corresponds to 105 230 tonnes in 2013.

7.3 The fishery in 2012

7.3.1 Description and development of the fisheries

Distribution of the 2012 Norwegian spring-spawning herring fishery for all countries by ICES rectangles per year is shown in Figure 7.3.1.1 and for annual quarter in Figure 7.3.1.2.

The 2012 herring fishing pattern was similar to recent years, i.e. clockwise movement of the fishing fleet in the Norwegian Sea as the year progressed. The fishery began in January on the Norwegian shelf and focused on pre-spawning, spawning and post-spawning fish (Figure 7.3.1.2 quarter I). By spring, fishing effort had shifted south to Icelandic and Faroese waters (Figure 7.3.1.2 quarter II) and expanded north to Svalbard in summer, hence, covering the whole western part of the Norwegian Sea (Figure 7.3.1.2 quarter III). In fall, fishing shifted to the eastern part of the Norwegian Sea (Figure 7.3.1.2 quarter IV). The largest proportion of the catches was taken in the fourth quarter (45 %). Before 2010 the fishery in fourth quarter tended to be primarily in the wintering area in the Norwegian zone, but in recent years there have also been fisheries in the international (<68°N), Icelandic and Faroese EEZs.

In 2012 there were no limitations for countries to enter the EEZs of other countries according to bilateral negotiations regarding Norwegian spring-spawning herring.

The NSSH changed wintering areas from fjordic to oceanic during the years 2002-2006. The new wintering pattern caused a large change in fishing pattern as more catches were taken during the spawning migration and spawning instead of during the wintering period. The changes apply mostly to the Norwegian fleet and are discussed in section 7.3.1.8.

[1] Agreed record of conclusions of fisheries consultations on the management of the Norwegian spring-spawning (Atlanto-scandian) herring stock in the north-east Atlantic for 2012 (London, 14 October 2011).

[2] Agreed record of conclusions of fisheries consultations on the management of the Norwegian spring-spawning (Atlanto-scandian) herring stock in the north-east Atlantic for 2013 (London, 23 January 2013).

[3] Press release by the Faroese Ministry of Fisheries 26-03-2013 | The Faroese fishery for Atlanto-Scandian herring in 2013

7.3.1.1 Denmark

The Danish fishery of Norwegian spring spawning herring did in 2012 take place in IIa by purse seiners and trawlers. A total sum of 21 783 tonnes was caught of which 9 236 tonnes were taken in January, 2 244 tonnes in February and 10 273 tonnes in the fourth quarter.

7.3.1.2 Germany

The vessels targeting Norwegian spring spawning herring belong to the pelagic freezer trawler fleet owned by a Dutch company and operating under the German flag. Depending on season and the economic situation these vessels are targeting other pelagic species in European and international waters. This fleet consists of four large pelagic freezer-trawlers with power ratings between 4 200 and 12 000 hp and crews of about 35 to 40 men. The vessels are purpose built for pelagic fisheries. The catch is pumped into large storage tanks filled with cool water to keep the catch fresh until it is processed. The reported landings in 2012 were 11 945 tonnes taken in IIa and IIb.

7.3.1.3 Greenland

The bulk of the catches was taken in Division IIa, while the remaining was caught in both Division Va and Subarea XIV, partly as an exploratory fishery.

7.3.1.4 Faroe Islands

The Faroese herring quota was 42 983 tonnes in 2012 and the total catch was 36 190 tonnes. Majority of herring catches was caught within the Faroese EEZ (77 %), and a smaller portion in international waters (14 %) and the Norwegian EEZ (9 %). Approximately 65 % of catches were caught in the direct herring fishery, which occurred in fall (September to November) whereas 33 % was by-catch in the summer (May to August) mackerel fishery. Herring was caught within the Faroese EEZ from May to November but the location of the fishery shifted between seasons. In early summer, the fishery was concentrated between latitudes 62 °N to 64 °N, just north of the Faroe Islands. By August the fishery was concentrated in the north western section of the Faroese EEZ whereas in fall the fishery shifted to the north eastern section. Faroese fishing vessels did not catch any herring in winter (January – April) excluding a small catch in the Norwegian EEZ in January.

The 2012 herring fishing season in Faroese waters lasted seven months. A trend of prolonged herring fishing in Faroese EEZ has been observed annually since 2008. In summary, from 2008 to 2012, herring fishing in Faroese waters began in May and continued until November.

7.3.1.5 Iceland

The Icelandic TAC for Norwegian spring spawning herring in 2012 was set at 121 000 tonnes. The majority of the catch, or 97 000 tonnes, was caught within the Icelandic EEZ in the period June to November, like in last year. This is a clear indication for a prolonged existence of the stock on feeding grounds in the west, including Icelandic waters, where in the years before the fishery moved to International or Norwegian waters already in September to October. The remaining catch of 24 000 tonnes was caught within the Faeroese EEZ. The total catch of the Icelandic fleet in 2012 came to 120 956 t.

Since 2007 the entire fishery of the Icelandic summer-spawning herring was west off Iceland and therefore Norwegian spring-spawning herring was not caught in that fishery, different from the east coast fishery during 2004-2005.

7.3.1.6 Ireland

The Irish fishery for Norwegian spring spawning herring took place in February off the Norwegian coast. A total of 7 vessels participated in the fishery and recorded landings of 4 800 tonnes. Norwegian spring spawning herring from the Irish fleet are landed primarily for reduction to fishmeal and processed for human consumption. All landings were made into Norwegian ports.

7.3.1.7 Netherlands

Two Dutch freezer trawlers participated in the fishery for Norwegian spring spawning herring in 2012. The fishery took place in September and October, mostly in ICES Division IIb. The Dutch catch of 62 000 tonnes was taken in 2 trips. The fishery is carried out with large pelagic trawls. By-catches in the fishery consisted of blue whiting (82 tonnes) and mackerel (5 tonnes).

7.3.1.8 Norway

The Norwegian quota for 2012 was shared with about 50% to the large oceanic purse seiners, 10% to trawlers and 40% to smaller coastal purse seiners. The total catch during the first quarter in 2012 was 237 534 tonnes. The Norwegian fleet hardly fish herring in the oceanic feeding area during the second quarter. There are some catches reported from the coastal areas during this period, amounting to 836 tonnes in 2012. This herring consists of a mix of NSSH, a summer spawning oceanic stock and local fjordic herring stocks, of which the two latter are allocated to the Norwegian spring spawning herring quota for practical reasons. The Norwegian fisheries after the feeding period in quarter 3 started in the areas west of the Lofoten Isles, about 200 nautical miles from land, and then moved northeast towards the oceanic wintering area north of Vesterålen. A total of 12 426 tonnes were caught in the third quarter. The fisheries in the fourth quarter took place on the wintering areas west and northwest of Vesterålen and in fjords in Troms, and the catch was 240 136 tonnes.

7.3.1.9 Russia

The Russian fishery started within the wintering area of the Norwegian spring spawning herring (approximately 10 – 15°E) in the Vesteralen (Norwegian EEZ) at the beginning of January, then progressed in the south-western direction along the Norwegian coast and was finished on south banks of the Norwegian shallow water (approximately 63°N) at the second half of February. In January-February the total catch was 12 335 tonnes.

During the II quarter the Russian fleet did not target herring. Herring was caught in mackerel fishery only. The total catch was 64 tonnes.

In III quarter, Russian fishery started in august. The vessels caught herring in the international waters and in areas of Spitsbergen and Jan-Mayen westward from 16° E. 46 462 tonnes of the herring was taken in the III quarter.

In IV quarter, the fishery was continued in area of Spitsbergen and international waters. At the end of November Russian fishery started in the Norwegian EEZ. Catch was finished in December. 59 734 tonnes was taken in that period.

The Russian fishery is carried out by different types of trawl vessels. Total Russian catch of Norwegian spring spawning herring was 118 595 tonnes. The entire Russian catch was utilized for human consumption.

7.3.1.10 UK (Scotland)

Fifteen Scottish vessels took part in the IIa NSSH fishery in 2012. All landings, 12 310 tonnes, were taken in the first quarter. 86% of the landings were made into Norway.

7.3.2 Information on by-catch

In recent years the Faroes has reported on problems with mackerel caught as by-catch in the directed herring fishery north of the Faroes. However, since 2010 the fishery has been directed towards herring and mackerel in the Faroese zone, and has thus been a result of legal activity.

7.4 Stock Description and management units

7.4.1 Stock description

A description of the stock is given in section A.1.1 in the stock annex.

7.4.2 Changes in migration

A characteristic feature of this herring stock is a very flexible and varying migration pattern. A detailed description of the migration pattern is given in the stock annex.

Information about changes in migration of the stock in recent years is mainly derived from the ecosystem surveys Nordic Seas in May (ICES 2013c) and July/August (Nøttestad et al. 2013). The May survey takes place when the stock is still, in part, migrating to the feeding grounds and there are no major changes in migration pattern and distribution of the stock observed in recent years. The main concentration has been in the mid Norwegian Sea with a tail reaching southwest into Faroese and Icelandic waters and typically a smaller concentration further north towards Lofoten in Norway. The July/August survey shows a further westwards and northwards migration, with the main concentrations in the south-western to north-western fringes of the Norwegian Sea. However, the main changes in the stock's migration pattern observed in recent times derive from information from the commercial fishery. They indicate an extended occurrence of herring staying on the feeding grounds in the western part, with fishery ongoing in Faroese and Icelandic waters reaching into November in recent two years, in contrast to September and October earlier. Such indications resulting from fishing activity have to be interpreted carefully as the behaviour of the fleet can also have changed, causing the changes in distribution of catch from one year to another.

It is not clear what drives the changes in the migration, but the biomass and production of zooplankton is a likely factor, as well as oceanographic features (e.g. limitations due to cold areas). However, it should be noted that beside the environmental forces the age distribution in the stock is also likely to influence the centre of gravity of the stock during summer (Figure 7.4.2.1). At present the stock consists of old individuals due to poor recruitment in a number of years, and as the largest fish move farthest west, the stock should be in the western areas at the time being while the opposite should be expected when rich year-classes join the adult stock from the nursery areas in the Barents Sea.

7.5 Data available

7.5.1 Catch data

Data-delivery sheets from Denmark, Faroe Islands, Germany, Iceland, Ireland, The Netherlands, Norway, Russia, Scotland and Sweden were available with data from 2012. From Greenland only catches in tonnes were delivered. The data delivery sheets contain total catch in tons by quarter of the year and ICES area. Catch in tonnes by ICES rectangles and quarters are also reported.

The total working group catch in 2012 was 826 000 tonnes (Table 7.5.1.1) compared to the ICES-recommended catch of 833 000 tonnes. The catches were taken in ICES areas: IIa, IIb, IVa, Va, Vb and XIVa. The majority of the catches were taken in area IIa as in previous years.

Samples were not provided by Greenland, The Netherlands, Scotland and Sweden (text table in section 1.3.2). Sampled catches accounted for 93% of the total catches, which is similar to previous years. The sampling levels of the catch in 2012 by country are shown in Table 7.5.1.2. The program SALLOC (ICES 1998/ACFM:18) was used to provide catches in numbers (Table 7.5.1.2).

7.5.2 Discards

In 2008, the Working Group noted that in this fishery an unaccounted mortality caused by fishing operations and underreporting probably exists. It was not possible to assess the magnitude of these extra removals from the stock, and taking into account the large catches taken in recent years, the relative importance of such additional mortality is probably low. Therefore, no extra amount to account for these factors has been added in 1994 and later years. In previous years, when the stock and the quotas were much smaller, an estimated amount of fish was added to the catches.

The Working Group has no comprehensive data to estimate discards of the herring. Although discarding may occur on this stock, it is considered to be low and a minor problem to the assessment. This is confirmed by estimates from sampling programmes carried out by some EU countries in the Data Collection Framework. Estimates on discarding in 2008 and 2009 of about 2% in weight were provided for the trawl fishery carried out by the Netherlands. In 2010 and 2012, this metier was sampled by Germany. No discarding of herring was observed (0%) in either of the two years.

During the Norwegian fishery in the first quarter the stock is migrating fast southward in dense aggregations. This is a challenge to the fleet by increasing the risk of slipping of the catch or breaking of the net during fishing operations due to extremely large catches. There are no data to estimate the amount of slipping. However, the Coastguard maintains a close presence with the pelagic fishing fleet during the season with several vessels and a plane. IMR has cooperation with a number of reference vessels in the pelagic fleet, primarily for the purposes of biological sampling but also recording losses through gear damage or slipping. These data indicate that the frequency of slipping and the total quantities of fish slipped are low and, although the quantity remains unknown, are too small to have a significant effect on the reliability of the assessment.

7.5.3 Length and age composition of the catch

In 2011 about 60% of the catches both in numbers and in weight were taken from the year classes from 2002, 2003 and 2004. In 2012 around 30% of the catches, both in numbers and weight, were taken from the 2004 year class. The catches from the year classes 2002, 2003, 2005 and 2006 were similar, each around 12% in number and 13% in weight. Around 8% of the catches in number (5% in weight) in 2012 were taken from the 2009 year class, but this year class contributed a high number in catches at age 2 in 2011 already.

For the year 2012 a 7% higher catch of the year classes 1998 and 2002 was predicted than was observed and the other way round for the 2009 year class.

The catch at age data are given in Table 7.5.3.1. Lengths at age data are not used in the assessment.

7.5.4 Weight at age in catch and in the stock

The weight-at-age in the catches in 2012 was computed from the sampled catches in 2012 using the SALLOC software. Trends in weight-at-age in the catch are presented in Figure 7.5.4.1 and Table 7.5.4.1. The mean weights at age for most of the age groups have been at similar level as in mid 2000s, however the mean weight for ages 3 to 5 have been slightly increasing in the last two years.

A similar pattern is observed in weight-at-age in the stock which is presented in Figure 7.5.4.2. These data have been taken from the survey in the wintering area until the year 2008. The mean weight at age in the stock for age groups 4-11 in the years 2009-2013 was derived from samples taken in the fishery in the same area and at the same time as the wintering surveys were conducted in. The weight at age in the stock is given in Table 7.5.4.2.

7.5.5 Maturity at age

The maturity data used in the assessment were revised in 2010 following a recommendation from WKHERMAT[4]. This Workshop evaluated the existing maturity at age data because they were not available or considered in the benchmark assessment in 2008.

WGWIDE adopted the maturity o-gives derived from back calculation of scales for the historical time period (years 1950-2007) in the assessment. WGWIDE recommends that this data set remains updated in future years. For the years after 2007 for which no data are available from this method (including the years considered in the forecast) the following default maturity o-gives will be assumed. For 'normal' classes (average, median and weak year classes), an average maturity at age will be assumed from the periods 1983-2007 from the back calculation data set excluding the strong year classes 1983, 1991, 1992, 1998, 1999, 2002. For year classes which are considered strong, preliminary estimates will be assumed to be the average of the recent strong year classes 1983, 1991, 1992, 1998, 1999, 2002 in the data set.

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[4] Report of the Workshop on estimation of maturity ogive in Norwegian spring spawning herring (WKHERMAT). 1-3 March 2010 Bergen, Norway. ICES CM 2010/ACOM:51 REF. PGCCDBS

The default maturity o-gives used for 'normal' and strong year classes are given in the text table below.

AGE	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
normal yc	0	0	0	0	0.4	0.8	1	1	1	1	1	1	1	1	1	1
strong yc	0	0	0	0	0.1	0.6	0.9	1	1	1	1	1	1	1	1	1

The maturity ogives used in the present assessment are presented in Table 7.7.5.1.

7.5.6 Natural mortality

In this year's (2013) assessment, the natural mortality M=0.15 was used for ages 3 and older and M=0.9 was used for ages 0–2. These levels of M are in accordance to previous years and their justification is provided in the stock annex. Information about deviations from these levels in the time series, e.g. due to diseases, are also provided in the stock annex.

7.5.7 Survey data updated

The description of the surveys and use of them for tuning in the assessment are given in the Stock Annex 2. This section contains and discusses the survey results from the some recent years. Several surveys were stopped many years ago, but are still used for tuning of the assessment models because they were included in the benchmark. The influence of these surveys on the assessment and the need to use them in the future should be investigated in the next benchmark assessment.

7.5.7.1 Survey 1 Norwegian acoustic survey on spawning grounds in February/March (NASF)

No new information but the years 1994-2005 are used in the tuning (see stock annex 2)

7.5.7.2 Survey 2 Norwegian acoustic survey in November/December (NASN)

No new information but the years 1992-2001 are used in the tuning (see stock annex 2)

7.5.7.3 Survey 3 Norwegian acoustic survey in January (NASJ)

No new information but the years 1991-1999 are used in the tuning (see stock annex 2).

7.5.7.4 Survey 4 and 5 International ecosystem survey in the Nordic Seas (IESNS)

The international ecosystem survey in the Nordic Seas aims for exploring the pelagic ecosystem, with a special focus on herring, blue whiting, zooplankton and hydrography. Survey coverage in the Norwegian Sea was considered adequate in 2013 and in line with previous years. It is therefore recommended that the results can be used for assessment purpose. The herring distribution in 2013 was similar to the 2012 distribution (Figure 7.5.7.4.1). High concentrations were found in the central to southwestern part of the Norwegian Sea with particularly high concentrations in the south and in the north of this area. A third main concentration was found in the northeast (around 68°N and 10°E). Overall the herring density was relatively low and herring was never observed in big schools. In 2013, like in 2012 and 2011, almost no herring were observed north of 70°N, while it was found further north in 2010.

As in previous years the smallest fish were found in the eastern area where size and age were found to increase to the west and south. Correspondingly, it was mainly older herring that appeared in the southwestern areas (area III), especially the 2003 and 2004 year classes, compared to mainly the 2004 year class further east and the 2009 year class furthest north.

The herring stock is now dominated by 9 year old herring (2004 year class) in numbers but 7, 8, 10 and 11 year old herring (the 2006, 2005, 2003 and 2002 year classes) are also numerous (Figure 7.5.7.4.2). The 2009 year class appears to be the largest of the younger age groups even if it is relatively small in historical perspective. However, this year class is almost absent in the Barents Sea Survey, suggesting it might have been growing up in the fjords. The five year classes from 2002 to 2006 contribute to 10%, 14%, 23%, 14% and 10%, respectively, of the total biomass.

The total biomass estimate of herring from the 2013 survey was 5.4 million tonnes. This estimate is 0.8 million tonnes higher than in 2012. The biomass estimates in recent five years has fluctuated, with 10.7 million tonnes in 2009, 5.8 million tonnes in 2010, 7.4 million tonnes in 2011, 4.6 million tonnes in 2012 and now 5.4 million tonnes. The uncertainty, or the CV, round the estimates is unknown, but might be considerable considering the recent fluctuations, even if the downward trend in the biomass is apparent.

In the Barents Sea the investigations of herring covered the area from 33°E to the 20°30′ E. Relatively low concentrations of herring were found in the Barents Sea. The total abundance estimate in 2013 was low, although higher than in 2012, 1912 million individuals of age 2 (mean length of 17.5 cm and mean weight of 31.5 g) and 377 million individuals of age 4 herring (mean length of 23.5 cm and mean weight of 83.0 g). Only very few 1-year old and 4-year old herring were observed. So even though a moderate level of 4-year-olds is observed in the Norwegian Sea, there is very little of that year class of 2009 in the Barents Sea. This might be due to this age class growing up in the fjords and not in the Barents Sea.

The time-series of abundance (both in numbers and biomass) of Norwegian spring-spawning herring in May is shown in Table B.3.4.2 in the stock annex. The total number of herring recorded in the Norwegian Sea was 13.0 billion in the northeastern area and 7.4 billion in the southwestern area, compared to 12.8 billion and 7.2 billion last year, respectively. Thus the slight increase in the abundance estimate compare to 2012 was in the northeastern area about 2% and in the southwestern area about 3%.

The age-disaggregated time-series of abundance for the Barents and Norwegian Sea are presented in Table 7.5.7.4.1 and 7.5.7.4.2, respectively.

7.5.7.5 Survey 6 and 7 Ecosystem survey in the Barents Sea (Eco-NoRu-Q3 (Aco))

The age groups 1 and 2 are used in the assessment. The log index of 0–group herring has been used in the assessment up to 2004 and then replaced by a new abundance index, which was included in the assessment since 2006.

The results from these surveys on 0–group herring are given in Table 7.5.7.5.2; those of the 1 to 3 age groups are given in Table 7.5.7.5.1.

Since 2004 no strong year classes of Norwegian spring spawning herring has been observed in the Barents Sea. This situation continued in the autumn 2012 where the number of juvenile herring was estimated to be 4.4 billion individuals, which is approximately three times more than last year, but this abundance estimate was significantly less than the average abundance during the period 1999 to 2011. Spring spawning herring was not found in the south-eastern part and only very scattered concentrations were found in the western part of the Barents Sea, along coast of Norway and Russia. Herring in age groups 1-3 was registered but the three-year-old dominated.

The distribution of young herring is shown in Figure 7.5.7.5.1. Distribution of 0–group herring is presented in Figure 7.5.7.5.2.

7.5.7.6 Survey 8 Norwegian herring larvae survey on the Norwegian shelf (NHLS)

A description of this survey is given in stock annex 4. Two indices are available from this survey (Table 7.5.7.6.1). The "Index 1" is used in the assessment as representative for the size of the spawning stock except for 2003 and 2009 due to incomplete coverage in these years.

In 2013 the survey was carried out from 02 to 18 April. The number of herring larvae was estimated to be $71.6*10^{12}$, resulting in a Larvae Production Index (LPI) of 345.3. The number of larvae is slightly higher than last year while the estimated production of larvae is slightly higher compared to last year (Table 7.5.7.6.1). The weighted mean size of the larvae was 13.54 mm which is one of the highest in the time series. Most of the larvae were in first feeding stages (2a) and very few yolk sac larvae were found.

As shown in figure (Figure 7.5.7.6.1), herring larvae were observed throughout the sampling area. Zero values were found on the southernmost sections but relatively high concentrations on the northernmost section. Therefore, the northern extent was not defined. The offshore extent of the larval distributions were found on all transects. The highest abundance of herring larvae were found relatively close inshore, on the northern part of the Møre spawning grounds and northward to Haltenbanken. Relatively low concentrations of larvae were found on the northern spawning banks of Lofoten, Vesterålen and Troms.

7.5.7.7 Survey 9 International ecosystem survey in the Norwegian Sea in July-August (IESSNS)

The survey (formerly called "Norwegian ecosystem survey and SALSEA salmon project in the Norwegian Sea in July-August") has been carried out on the Norwegian shelf since 2004 for the exception 2007 but was extended to the whole Norwegian Sea, Icelandic waters, and Faroese waters in 2009. The objectives of the survey are to obtain estimates of abundance, spatiotemporal distribution, aggregation and feeding ecology of Northeast Atlantic mackerel, Norwegian spring-spawning herring, blue whiting and Atlantic salmon in relation to oceanographic conditions, prey communities and marine mammals.

The survey has not been used in the assessment of NSS herring but the results from the surveys, with regards to herring, plankton and hydrographical investigation, has been presented to the WG every year. Four vessels from Norway (2), Iceland (1) and Faroe Island (1) participated in the survey in 2013 during 2 July to 9 August. The acoustic estimate of NSSH in the survey came to 8.6 million tonnes compared to 7.3 million tonnes in 2012, 10.7 million tonnes in 2010 and 13.6 million tonnes in 2009. There is no estimate from 2011 due to insufficient coverage.

7.6 Methods

7.6.1 TASACS stock assessment

The preliminary assessment for 2013 was run as an update assessment using the VPA population model in the TASACS toolbox with the same model options as the benchmark in 2008 (see stock annex 4). The information used in the assessment is catch data and survey data from eight surveys. The analysis was restricted to the years 1988 – 2013, which is regarded as the period representative of the present production and exploitation regimes, and is presumed to be of main interest for the management.

The preliminary assessment revealed the same strong retrospective patterns as have been observed since assessment year 2010. However, adding the latest catch statistics and survey information lead to unexpectedly large changes in the perception of the stock, particularly in the earlier period of the assessment time series (see WD Skagen 2013 and data exploration below) that were considered to be out of proportion. As a result of the data exploration WGWIDE implemented an updated algorithm for calculating the terminal F-values for last age classes where no data supporting the estimate of terminal stock numbers was available. The derivation of this algorithm is described in section 7.7.3.2 on Data exploration.

The model was run with catch data 1988 – 2012, and projected forwards through 2013 assuming Fs in 2013 equal to those in 2012, to include survey data from 2013.

7.6.2 Short-term forecast

A detailed description of the short term forecast procedure is given in the stock annex. Since the standard software cannot cope with Management Option Tables based on average fishing mortality weighted over stock numbers, calculations are carried out using a spread sheet.

7.7 Data Exploration

7.7.1 Catch curve analyses

Catch curve analyses on commercial catches

Figure 7.7.1.1 shows the age disaggregated catch in numbers by years. Since 2007 the year class 2002 has been the most prominent year class in the catches. In 2011 it was at similar levels to the 2003 and 2004 year classes, whereas it is in 2012 at similar levels to the 2003 year class, with the 2004 being the largest one. Figure 7.7.1.2 shows the disaggregated catch in numbers plotted on a log scale. For comparison, lines corresponding to Z=0.3 are drawn in the background. It is tempting to draw the conclusion that the catch curves shows the exploitation of the big year classes in the periods of relatively constant effort, but the poor year classes exhibit just noise. For year classes 2005 and younger these curves provide hardly any information.

Catch curve analyses on survey catches

Survey 5

For survey 5 Figure 7.7.1.3 shows the disaggregated catches in numbers plotted on a log scale. The same arguments are valid for the interpretation of the catch curves from the survey as from the catches. In 2010 the number of all age groups decreased suddenly and this is seen as a drop in the catch curves that year. This drop has continued for some of the year classes and the year classes 1998 and 1999 are disappearing faster from the stock than expected. This observed fast reduction in these age classes may also be influenced by the changes in the Survey 5 catchability, with seemingly higher catchability in years 2006-2009. Like for the catch data these provide hardly any information for year classes 2005 and younger.

7.7.2 data exploration with TISVPA

WGWIDE 2013 carried out some exploratory assessments with the TISVPA model, using the same version which was used by the Working Group in 2006 and later years. The main model settings were the same as in previous assessments.

The surveys data are taken the same as in the TASACS model run: the survey on spawning grounds along the Norwegian coast (survey 1); in wintering area in Vestfjorden in November-December (survey 2); in wintering area in Vestfjorden in January (survey 3); of young herring in the Barents Sea in May (survey 4); in feeding areas in the Norwegian Sea in May (survey 5); joint IMR-PINRO ecosystem survey in August-September (survey 6); Indices for 0 group (survey 7); and larvae index of SSB (survey 8). In contrast to the benchmark assessment, no data points were down-weighted.

Profiles of the components of the TISVPA loss function with respect to SSB in 2013 are shown on Figure 7.7.2.1. As it can be seen, only catch-at-age data and survey 5 clearly indicate the SSB value in 2013 to be about 5 million tonnes; among others only survey 4 gives similar weak indication as local minimum, while other surveys give unclear and contradicting indications. If still to retain inputs from all data sources the overall objective function indicates the SSB in 2013 to be higher than 6 million tonnes (curve 9 in Figure 7.7.2.1).

Since the survey 1-3 were not conducted in recent years and their influence on the solution is rather indirect and weak, the same way as in last year assessment these three surveys were excluded from the consideration, as well as the other surveys giving no proper indication about the stock in 2013. In such a case, if to retain in the objective function of the model only components from catch-at-age and survey 5, the SSB in 2013 is estimated about 5 million tones (curve 10 in figure 7.7.2.1).

Retrospective runs made using inputs only from catch-at-age and survey 5 data still reveals strong historical bias in the results of the assessment by TISVPA (figure 7.7.2.2), generally similar to what is observed in the TASACS results.

The above mentioned historical bias in the stock biomass estimates can be somewhat diminished if only catch-at-age data is used in the assessment (figure 7.7.2.3). Let us remind that TISVPA, being a separable model and implementing some robust approaches, gives possibility to look for single solution of general system of cohort analysis equations without auxiliary information.

The results shown in figure 7.7.2.3 also show that the data of survey 5 can serve as a possible source of the historical bias observed in the results of the assessment, possibly due to historical changes in the survey catchability.

Since that, an additional set of TISVPA runs was made when the survey 5 data were used as the only source of auxiliary data and the model objective function included the only one component, corresponding to the median if the distribution of weighted squared residuals between logarithmic age proportions in the data of the survey 5 and the respective values, coming from cohort part of the model. Tuning not at survey-derived abundance values but at age proportions helps to exclude the impact of possible year-to-year changes in survey catchability. As it can be seen from figure 7.7.2.4, such an approach helped to significantly diminish the above mentioned historical bias in the assessment.

The TISVPA residuals for survey 5 for each of the retrospective runs made for the case when the model was tuned only at age proportions of survey 5 are show in the figure 7.7.2.5. As it can be seen, negative residuals are prevailing for final years, especially in the terminal year. Consequently, if to give “full power” to the survey data, that is to use them as a measure of absolute abundance in the procedure of tuning of a model, they would pull upwards the biomass estimates for terminal year.

As it can be traced by a comparison of changes in residuals for, for example, year 2010 in all the four graphs of the figure 7.7.2.5, the residual are gradually diminishing by absolute value in the later model runs, when the data for additional years are adding and new, higher, average values of the survey catchability are estimating and being used in the model. This conclusion is also supported by Figure 7.7.2.6 representing the TISVPA-derived estimated values of average catchability by ages for survey 5 obtained in retrospective runs.

That is, the observed historical bias in stock assessment results could probably be attributed to gradual increase in survey 5 effective catchability in recent years due to, for example, more compact and “surveyable” stock distribution as a result of lower number of different age classes in the stock.

In general, the results of the TISVPA runs support the conclusions drawn from investigations of the bias in historical runs of the TASACS model.

7.7.3 TASACS assessment

7.7.3.1 Update benchmark assessment

The preliminary assessment run as an update following benchmark lead to unacceptably high changes in the perception of the stock, also in the historic time period. The features of the preliminary assessment justifying the deviation from benchmark are discussed in chapter 7.7.3.2. Data exploration in TASACS. The final assessment is described in section 7.7.3.3. Final assessment.

7.7.3.2 data exploration with TASACS

Preliminary runs with TASACS following the 2008 benchmark revealed the same strong retrospective patterns as have been observed since assessment year 2010. NSSH assessment is known to have a bias, and compared to the 2012 assessment the stock has been overestimated by on average 20% during the years when TASACS has been used as the assessment model (ICES 2013d, Figure 7.7.3.2.1 and Figure 7.7.3.2.2). Retrospective patterns have been observed also in previous assessment years (Figure 7.7.3.2.3), highlighting the tendency to having a retrospective pattern that seems to have underestimated growing stock and overestimated decreasing stock. Particularly alarming is how including one more year’s data can change the perception of the stock more than two decades back in time. Figure 7.7.3.2.4 shows how the perception of the biomass of certain year classes in year 2008 has changed trough different assessments starting from 2008 and ending with the preliminary assessment 2013. In some cases the difference with the highest and lowest estimate is several million tonnes of biomass. It is clear that such a retrospective pattern is highly undesirable and undermines the credibility of an assessment.

The model fit to the tuning data is shown with Q-Q plots in Figure 7.7.3.2.5. Surveys 2-3 seem to fit rather well to the assumed linear relationship assumed in the TASACS model but surveys 4 and 6-8 have rather poor fit. In addition, the fitting of survey data to the model in different assessment years is not in all cases very good. Particularly Surveys 7 (0-group) and 8 (larval survey) seems to disagree a lot with the assessment (Figure 7.7.3.2.6).

In a Working Document to WGWIDE 2013 Skagen[5] explored possible reasons for this retrospective pattern. The WD compares the assessment from 2012 with the preliminary assessment in 2013. Figure 7.7.3.2.7 shows the changes in the estimates of N-values at age 14 from 2012 to 2013 assessment for some of the year classes that have past the oldest true age of 14 years. Particularly the 1998 year class has been dramatically reduced. This reduction appears to feed back all the way to the recruitment estimates of year classes of 1990's, which is demonstrated in Figure 7.7.3.2.8 showing the change in estimates of year class strength (N-values back-calculated to age 1) from 2012 to 2013 assessment. Such changes that trickle all the way back to recruitment make the assessment rather unstable and increase the uncertainty in the stock estimates.

Two possible ways to reduce the instability in the assessment were explored: 1) adjusting the catchability of the survey 5 (May survey) during the period where there seems to have been unusually high catchability, and 2) updating the algorithm for estimating the terminal F values for year classes where no supporting data is available.

In the benchmarked procedure the catchability of the surveys is estimated every assessment year over the whole period (from 1988 or the starting year of the survey to the assessment year) and kept constant. The residuals from survey 5 seem to have first a series of negative residuals and then a block of positive residuals in years 2006-2009 (Figure 7.7.3.3). When residuals from survey 5 from previous years' assessments are examined, it is apparent that this change in residual pattern has been building gradually (7.7.3.2.11). WGWIDE acknowledges that there appears to be changes in the survey catchability of survey 5 that influence our perception of the stock (WD Skagen WGWIDE 2013). An exploratory run using separate catchability estimates in the period in which large positive residuals are observed (2006-2009), significantly reduces the retrospective pattern in the recent years (Figure 7.7.2.12). This is also supported by the exploratory assessment with TISVPA using only the age signals from the survey but not the abundance (section 7.7.2.). However, understanding and documenting the variation in survey catchability is a task that was not possible to undertake during WGWIDE 2013 and needs to be followed up in the next benchmark for this stock.

There are no data to estimate the terminal stock numbers for some small year classes in the VPA (before 1982, 1984 – 1988, 1995 and 2000 – 2001). In the 2008 benchmark the derivation of the terminal fishing mortalities for those of these year classes that had reached oldest true age, was defined as derived from the terminal F the year before and fishing mortalities at younger ages, with the standard procedure in TASACS. However, because of the sensitivity of this method to noise particularly in the estimates of older age groups, Skagen (WD to WGWIDE 2013) suggests a new algo-

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Working document to WGWIDE: Dankert Skagen 2013. Exploring the assessment with TASACS.

rithm for this derivation. The new algorithm for deriving the terminal stock numbers for these year classes assumes a fixed ratio between F at oldest age and average F in the year, which is equivalent to assuming a fixed selection at oldest age. Similar method is used in the assessment model ICA, and in the separable option in TASACS. The ratio is taken from the selection parameters, as the selection at oldest age relative to the mean over the ages 5 - 13. There is no standard way to estimate that ratio. However, a sensitivity analysis showed that the the exact ratio used has only a minor influence on the estimated numbers in the earlier time period and none on the latest part of the times series. Values between 1.1 and 1.7 give comparable results. The ratio between the terminal F and the average F over ages 5-13 calculated for all the years where terminal F is estimated is 1.3 (excluding all F = 0), and this was applied in the current assessment.

Comparing the retrospective plots from the preliminary assessment and the assessment with the updated algorithm for terminal Fs shows a considerable improvement in the consistency of the assessment and lends support to the decision to the updated terminal F algorithm. Applying the new algorithm causes the retrospective pattern to almost disappear in the earlier period and reduces it in the recent years (Figure 7.7.3.2.9). In addition, the bootstrap diagnostics including the 'banana plot' show a marked improvement, the uncertainty shown by the preliminary run in the SSB in the earlier years is heavily reduced and the scattering in the banana plot is reduced (Figure 7.7.3.2.10 for the preliminary run and Figure 7.7.4.1 for the final assessment).

During the benchmark in 2008, exploration of the survey data was carried out in order to investigate whether the survey contributes information to the assessment or whether there is no or little information in the survey data. Within TASACS, the development of the individual cohorts (year classes) was explored for each survey separately. This was done cohort by cohort by translating each survey index into population numbers. This allows comparing what each survey indicates that the population numbers should be, and thus identify conflicting signals between surveys and outliers in the survey data. This was done year class by year class. Included in this analysis was also catch data at age, translated into N-values assuming a separable model for the fishing mortalities. Such comparisons allow identification of outliers in the surveys, contradicting signals, or may indicate that the survey provides mostly noise.

This year, new information was available for surveys 4, 5, 6, 7 and 8.

7.7.3.3 Final assessment

The final results of the assessment are presented in Tables 7.7.3.3.1 (stock in numbers) and 7.7.3.3.2 (fishing mortality) and Figures 7.7.3.1 and 7.7.3.5. Table 7.7.3.3.3 is the summary table of the assessment.

The assessment indicates that the fishing mortality ($F5 – 14_{weighted}$ weighted by stock numbers) in recent years has fluctuated between 0.12 and 0.19 and is estimated in 2012 at 0.144. The SSB in 2013 is estimated to 5.0 million tonnes.

7.7.4 Bootstrap

The uncertainty of the assessments was examined by bootstrap (1000 replicas). For the data where residuals are generated by the modelling, the bootstrap was made by adding randomly drawn residuals from the same source of data to the modelled observations. For catches at age in the VPA, log-normally distributed random noise with a CV of 0.1 was added to the observations. The results are shown in Figure 7.7.4.1.

7.7.5 Retrospective analyses

The retrospective analyses of the final assessment are shown in Figure 7.7.5.1. It shows that there is a retrospective pattern since the 2009 assessment, but the retrospective pattern previously observed in the earlier parts of the SSB time series has been considerably removed with the application of the new algorithm for terminal F-values (see also Figure 7.7.3.2.3 and Figure 7.7.3.2.7). The retrospective pattern is discussed under section 7.7.3.1.2.

7.8 NSSH reference points

ICES reviewed the reference points of Norwegian spring spawning herring in 2013 in combination with the NEAFC request to evaluate of alternative management plans for this stock. ICES concluded that B_{lim} should remain unchanged at 2.5 million tonnes. B_{pa} is not to be revised as it is defined based on B_{lim}. ICES has evaluated F_{MSY} and considers it should remain unchanged at F_{MSY} = 0.15[6].

7.8.1 PA reference points

The PA reference points for the stock originate from an analysis carried out in 1998, as detailed in the stock annex. According to it, ICES considers the precautionary reference points B_{lim}=2.5 million t and proposes that B_{pa}=5.0 million t. and F_{pa}=0.150.

7.8.2 MSY reference points

The MSY reference points originate from an analysis carried out by WGWIDE in 2010 and confirmed by reanalysis by WKBWNNSH in 2013. A detailed report of the analysis is provided in the stock annex. F_{MSY} is estimated at 0.15 and is based on the weighted mean of age groups 5-14. In the ICES MSY framework B_{pa} is proposed/adopted as the default trigger biomass $B_{trigger}$.

7.8.3 Management reference points

In the long term management plan the Coastal States have then agreed a target reference point defined at F_{target}=0.125 when the stock is above B_{pa}. If the SSB is below B_{pa}, a linear reduction in the fishing mortality rate will be applied from 0.125 at B_{pa} to 0.05 at B_{lim}.

7.9 State of the stock

The stock is declining and at B_{pa} in 2013. In the last 15 years, five large year classes have been produced (1998, 1999, 2002, 2004, and 2004). However, the available information indicates that year classes born after 2004 have been small. Fishing mortality in 2011 and 2012 is slightly below F_{pa} and F_{MSY}, but above the management plan F.

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[6] Norwegian spring spawning herring management plan operates on F values weighted with stock numbers, thus the unweighted F_{msy} is likely higher than 0.15.

7.10 NSSH Catch predictions for 2013

7.10.1 Input data for the forecast

The input stock numbers at age 1 and older have been taken from the final assessment as last year. No attempt was made to estimate recent year classes separately because the available information of these year classes from surveys had already be included in the VPA. It should be noted that recent year classes are estimated poor and have little influence on predicted catches and SSB. For age 0 a geometric mean (1988-2009) has been used as in previous years.

The catch weight-at-age, used in the forecast, is the average of the observed catch weights over the last 3 years (2010–2012). For the weight-at-age in the stock, the values for 2013 were obtained from the commercial fisheries in the wintering areas. For the other years the average of the last 3 years (2011−2013) was used.

Standard values for natural mortality were used. Maturity at age was based on the information presented in section 7.5.5. For all year classes born after 2004 the default maturity ogive for normal year classes were used

Like in 2012 the exploitation pattern used in the forecast was taken as the average of the last 5 years (2008−2012). The average fishing mortality defined as the average over the ages 5 to 14 and is weighted over the population numbers in the relevant year.

$$\overline{F}_y = \sum_{a=5}^{a=14} F_{y,a} N_{y,a} / \sum_{a=5}^{a=14} N_{y,a}$$

Where $F_{y,a}$ and $N_{y,a}$ are fishing mortalities and numbers by year and age. This procedure is the same as applied in previous years for this stock.

Input data for the short term forecast are given in Table 7.10.1.1.

7.10.2 Results of the forecast

The Management Options Table with the results of the forecast is presented in Table 7.10.2.1. Detailed output of the forecast, with options corresponding to the management plan is given in Table 7.10.2.2. Assuming a total catch of 692 000 tonnes is taken in 2013, it is expected that the SSB will decline from 5.0 million tonnes in 2013 to 4.1 million tonnes in 2014. The assumed catch in 2013 takes account for the TAC agreed by the Coastal States and the unilateral decided catch ceiling by the Faroe Islands.

As the spawning stock biomass in 2014 has dropped below the trigger reference point of 5 million tonnes, paragraph 3 of the management plan applies. This paragraph states that "*Should the SBB fall below the reference points of 5 million tonnes, the fishing mortality rate referred to under paragraph 2, shall be adapted in the light of scientific estimates of the conditions then prevailing to ensure a safe and rapid recovery of the SSB to a level in excess of 5 million tonnes. The basis for such adaptation should be at least a linear reduction in the fishing mortality rate from 0.125 at B_{pa} to 0.05 at B_{lim}*". The resulting fishing mortality used for predicting the TAC in 2014 = 0.099 and the corresponding TAC in 2014 is 418 000 tonnes. The expected remaining SSB in 2015 is about 3.5 million tonnes.

7.11 Uncertainties in assessment and forecast

7.11.1 Uncertainty in the assessment

The population dynamics of Norwegian spring spawning herring are characterized by occasional strong year classes that at turns dominate the stock. The occurrence of such high recruitment is impossible to foresee, and this increases the uncertainty in the assessment of this stock. This characteristic population structure also seems to have consequences for how well the surveys represent the overall stock – in the presence of strong year classes they are also dominating the survey sampling. There is marked changes in the survey catchability, the stock at times appearing to be more easily available for the survey leading to discrepancies between the signal given by the survey and the one given by catch statistics. This obviously increases the uncertainty in the assessment. Exploratory runs where the survey 5 catchability was changed for the period where we have a reason to assume higher catchability show smaller retrospective pattern in the latest years, which can be considered as decreasing the uncertainty of the assessment. It can be concluded that WGWIDE has identified variability in the survey catchability that increases the uncertainty in the assessment.

Final assessment in 2013 includes an updated algorithm for estimating the terminal F values for year classes where no supporting data is available. In these cases there is no information from the surveys and the catch statistics have a lot of stochastic noise. This update significantly reduces the uncertainty in the assessment, as it makes it more robust to the noise caused by small year classes entering age 14.

The Norwegian spring spawning herring assessment has been overestimating the stock biomass (5+) by on average 20% when 2012 assessment is compared to assessments from the years when TASACS has been used, i.e., 2008-2012 (ICES 2013d and Figure 7.7.3.2.2 and 7.7.3.2.13 in this report). Obviously this increases the uncertainty, though during the last 15 years the bias has been unidirectional. The reason for this bias is not understood, but might be related to the high variability in the year class strength.

7.11.2 Uncertainty in the forecast

In the past, the retrospective behaviour of the assessment, which is the basis for the forecast, has contributed to the uncertainty in the forecast and predicted catches have been taken with a higher fishing mortality than intended. This retrospective behaviour of the assessment is still apparent but is reduced between in the two most recent years. Also the present assessment is quite similar to last years.

There is little uncertainty about the fact that all year classes after 2004 are low. Recent year classes do not contribute significantly to the predicted catches. The fishery is mainly concentrating on the older age groups, which is apparent from the catch composition and the exploitation patterns in recent years. Assumptions on the actual size of recent year classes have little impact on the prediction of the catch and the SSB in the projected period.

Uncertainty in the forecast arises from the assumption of the catch which will be taken in the intermediate year in the forecast (2013). In previous years it was assumed that the agreed TAC, following from the management plan, will be taken in the intermediate year. In practice, this assumption appeared to be realistic. In 2013, however, the Faroe Islands has increased its national quota. Therefore the sum of the quota of all participants in the fishery is higher than the TAC agreed by the Coastal States.

In the forecast it has been assumed that the sum of the national quota will be taken in 2013.

7.12 Comparison with previous assessment and forecast

A comparison between the assessments 2008-2013 is shown in Figure 7.12.1. The assessment in 2013 was conducted in the same way as last year with the exception of the way the terminal F on the oldest age group was derived (see section 7.7.3.2). WGWIDE considers this to increase the stability in the assessment.

This year's assessment is consistent with last year's assessment. Fishing mortality is estimated slightly higher and SSB slightly lower than last year. The table below shows the SSB (thousand tonnes) in 2012 and F in 2011 estimated in 2012 and 2013.

	ICES2012	WG2013	%DIFFERENCE
SSB(2012)	6 136	5 832	-5%
F(2011)	0.134	0.142	+6%

The observed decline in the stock is consistent with previous assessments and forecasts. Last year it was expected that the SSB in 2013 would decline to 5.1 million tonnes compared to this year's estimate of 5 million tonnes. In the forecast for 2014, paragraph 3 of the Management Agreement has been applied for the 1st time. This paragraph applies when the SSB is estimated below B_{pa}, which appears to be the case in 2014. Consequently, the fishing mortality derived from the Management Agreement applied to the 2014 advice is lower than in previous years.

7.13 Management plans and evaluations

The long term management plan of Norwegian spring spawning herring was re-evaluated in 2013 (WKBWNSSH, ICES 2013d). This evaluation work was initiated by WGWIDE in 2012. ICES tested seven different harvest control rules including variants implementing F_{msy}, and two harvest control rules taking into account the entering of strong year classes, allowing for higher fishing mortality when knowledge of a strong year was available to the managers. ICES advised against increasing changing fishing mortality in the present management plan, and the reference points were recommended to be kept as they were. The present management plan is described in section 7.2. A brief history of it is in the stock annex. The management plan aims for exploitation at a target fishing mortality below F_{pa} and is considered by ICES in accordance with the precautionary approach. In general, the stock has been managed in compliance with the management plan. However, the realized fishing mortalities have been higher than intended under the plan due to the persistent overestimation of the stock during the last years (section 7.11.1). WKBWNSSH estimated that with the current management plan, the short-term probability of SSB < B_{lim} increases from 0.061 with no bias to 0.6 when a 20% bias is included (Figure 7.7.3.2.13).

7.14 Management considerations

Historically, the size of the stock has shown large variations and dependency on the irregular occurrence of very strong year classes. Between 1998 and 2004 the stock has produced a number of strong year classes which lead to an increase in SSB. The SSB for the year 2009 was estimated at its highest level in the last 20 years. Since 1999 catches have been regulated through an agreed management plan. The management plan is considered to be precautionary. However, in 2013, total declared catches are higher than the management plan.

In the absence of strong year classes after 2004, the stock has declined since 2009 and is expected to decline further in the near future even when fishing according to the management plan. New year classes mature between age 4 and 6. This means that it will take at least 4 years after they are born until they can contribute to an increase in the SSB. Surveys carried out in recent years in the Norwegian Sea and Barents Sea show no signs of new strong year classes after 2004.

The short term prognoses indicate a decline of SSB from 5 million tonnes in 2013 to 4.1 and 3.6 million tonnes in 2014 and 2015, respectively, assuming that declared catches will be taken in 2013 and exploitation in 2014 is according the management plan. SSB in 2014 is below B_{pa} and $B_{trigger}$. In that situation, article 3 of the management plan will be applied, to set TACs for 2014 and future years as long as SSB remains below B_{pa}. Given the low recruitment in recent years, it is expected that SSB will remain below B_{pa} in the short term. This situation will continue until large year classes appear and recruit in the spawning stock. It is worth noting that even zero catch will lead to SSB decreasing to levels below B_{pa} in 2014.

The results of the evaluation of a management plan are conditional to a number of assumptions which have to be made in any modelling exercise. The expected recruitment is one of these assumptions. In general, it is assumed that future recruitment patterns are similar as observed in the past. Under this assumption, the present management plan for Norwegian spring spawning herring is considered precautionary. However, the present extended period of low recruitment is an exceptional situation for this stock but may continue for a number of years. In the ICES advice, released earlier in 2013, on the NEAFC request to evaluate possible modifications of the management plan, an evaluation was presented of the expected dynamics of the stock under continued poor recruitment conditions. This evaluation indicates that in the absence of strong year classes entering SSB, under the present management plan SSB is expected to fluctuate around 4 million tonnes and catches will vary between 300 and 400 thousand tonnes.

In 2013, a lack of agreement by the Coastal States on their share in the TAC has lead to unilateral set quota's which together are higher than the TAC indicated by the management plan. If this situation continues, the high catches will accelerate the present decline of the stock and increase the risk of a depletion of the stock.

In recent years the distribution area of mackerel has expanded to the north and west and overlaps the distribution area of the herring in summer. As a consequence mackerel catches have been taken in that area as bycatch in the herring fisheries and in directed and mixed fisheries.

7.15 Regulations and their effects

The NSSH has been fished moderately for the last six years with an intended fishing mortality of 0.125. This is in accordance with the international management plan and below F_{pa}. Thus the stock is moderately harvested as compared to most other stocks.

7.16 Ecosystem considerations

The Norwegian spring-spawning herring is characterized by large dynamics with regard to migration pattern. This applies to the wintering, spawning and feeding area. Juvenile and adults of this stock form an important part of the ecosystems in the

Barents Sea, the Norwegian Sea, and the Norwegian coast. The herring stock is a significant part of the ecosystem in Nordic Seas, both as predator on zooplankton but also as food resource to higher trophic levels (e.g. cod, saithe, seabirds, and marine mammals).

Compare to the early 2000s, the older part of the herring stock have had more westerly feeding migration pattern in recent years according to the IESNS survey in May (ICES 2013c), which has been more pronounced in July/August according to the IESSNS survey (Nøttestad et al. 2013). With the absent of large recruiting year classes in the stock in recent years and thereby small amount of young herring, less amount have been feeding in the northeastern part of the Norwegian Sea. Thus herring have been mainly found in the fringe of the Norwegian Sea; i.e. from north of the Faroese, the east Icelandic area and north in the Jan Mayen area, with small concentrations in the central and eastern areas. Whether this distribution pattern is a response to feeding competition with mackerel, which is distributed over the whole Norwegian Sea and adjacent waters (Nøttestad et al. 2013), is unknown. A spatial overlap of herring and mackerel have been, and is still (Nøttestad et al. 2013), large in the southern most areas of the herring distribution, but less further north (e.g. in the Jan Mayen area). Spatial overlap between herring and mackerel causes bycatch of mackerel in the targeted herring fishery and vice versa in the mackerel fishery. In addition, fishery patterns suggest that herring appears to reside longer in the south-western area close to Faroese Island.

Analyses of stomach content of herring and mackerel overlapping spatially show that they are competing for food to some extent (Debes et al. 2012; Langøy *et al*. 2012; Óskarsson et al. 2012). Since mackerel is more effective feeder as for example indicated by the stomach content weight, herring might be partly outcompeted by the faster and more efficient mackerel in areas where they co-exist. Thus, the competition could be forcing the herring to the fringe of Norwegian Sea, even if more zooplankton biomass there (Nøttestad et al. 2013) could also attract the herring.

The average biomass of zooplankton in the total area in May had a decreasing trend from around 2002 until 2009, but an upward trend since then (ICES 2013c). An upward trend of zooplankton abundance was also observed in the IESSNS surveys for the years 2011-2013 (Nøttestad et al. 2013). At the same time (2011-2013), weight-at-age (this report) and length-at-age (ICES 2013b) in the stock are showing increasing trend. Thus, there are neither signs that the Norwegian Sea is being overgrazed at present by the pelagic fish stocks in the area, nor that the herring stock is starving, as was hinted at in last year’s WGWIDE report (ICES 2013a). N Further work on the zooplankton index is needed and is planned to be addressed by WGINOR (ICES 2013b). It involves revision of the data and producing indices for the different areas, as well as explorations of their relation to growth, abundance and spatial distribution of pelagic fish stocks feeding in the area.

7.17 Changes in fishing patterns

No major changes were observed in the fishing patterns in 2012 relative to recent years (see section 7.3). Minor changes observed include an extended period of the fishery in the southern and south-western areas in the Norwegian Sea during in 3rd and especially 4th quarters.

Mixture of mackerel and herring was again apparent in the 2012 summer fishery of the Icelandic and Faroese fleets, and the preliminary information from the fishery in

2013 in the Faroese zone also suggests a high degree of overlap between the two species.

7.18 Changes in the environment

In the Norwegian Sea, where the herring stock is grazing, the two main features of the circulation are the Norwegian Atlantic Current (NWAC) and the East Atlantic Current (EIC). The NWAC with its offshoots forms the northern limb of the North Atlantic current system and carries relatively warm and salty water from the North Atlantic into the Nordic Seas. The EIC, on the other hand, carries Arctic waters.

The Arctic front is a central feeding area for Norwegian spring-spawning herring. During periods when the Arctic front is shifted westwards it is likely that the part of the stock feeding in the western Norwegian Sea will also be shifted westward. In May 2013, the Arctic front was encountered slightly below 65°N east of Iceland extending eastwards towards the 0° Meridian where it turned almost straight northwards up 70°N (ICES 2013c). The front was visible throughout the observed water column but was most pronounced at deeper depths. The warmer North Atlantic water formed a broad tongue that stretched far northwards along the Norwegian coast with temperatures > 8 °C in the surface layers and >7 °C at 300 m depth.

Relative to an 16 years long-term mean, from 1995 to 2010, the average temperatures 0-200 m depth north of Iceland and northeast of the Faroese were considerable higher (~1°C) in 2013 compared to the long-term mean (ICES 2013c). At the surface this difference was larger north of Iceland but was less northeast of the Faroese. At larger depths, the anomaly northeast of the Faroese was higher or up to 2°C at 300m depth. In the central Norwegian Sea the temperature was mainly close to or lower than the long term mean at all depths. A comparison of the sea temperatures in 2013 and 2012 showed particularly warmer waters northeast of the Faroese in 2013, while colder waters (0.5° - 0°C) in the central Norwegian Sea.

7.19 Recommendation

The assessment of NSSH was benchmarked in 2008. The recent assessments for NSSH in 2013, carried out under benchmark conditions, shows large retrospective patterns suggesting that present estimates of SSB are overestimated and that fishing mortality is underestimated. WGWIDE proposes to carry out a benchmark for this stock in 2015. Amongst other things the benchmark must consider:

- exploration of alternative assessment models including different configurations of TASACS which produce more stable input values for the oldest age group
- investigate the bias in the assessment
- an analysis of variability or changes in the catchability of fleet 5. This is the major fleet used for tuning the assessment and seems to be causing retrospective patterns in the assessment
- the inclusion of a new tuning series (IESSNS) in the assessment
- the use of surveys in the assessment for tuning
- based on data, to be provided by the major fishing nations, whether estimates of slipping should be included in the assessment
- update maturity ogives for recent years following procedures as described by WKHERMAT.

- extend the time series used in the assessment with earlier years before 1988
- the need to continue the use of weighted average F in the assessment and advice. NSSH is one of the few stocks in which weighted F's are applied.
- the consequences for the reference points and management plans if the use of weighted F is discontinued

7.20 References

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Table 7.5.1.1 Total catch of Norwegian spring-spawning herring (tons) since 1972. Data provided by Working Group members.

Year	Norway	USSR/ Russia	Denmark	Faroes	Iceland	Ireland	Netherlands	Greenland	UK (Scotland)	Germany	France	Poland	Sweden	Total
1972	13161	-	-	-	-	-	-	-	-	-	-	-	-	13161
1973	7017	-	-	-	-	-	-	-	-	-	-	-	-	7017
1974	7619	-	-	-	-	-	-	-	-	-	-	-	-	7619
1975	13713	-	-	-	-	-	-	-	-	-	-	-	-	13713
1976	10436	-	-	-	-	-	-	-	-	-	-	-	-	10436
1977	22706	-	-	-	-	-	-	-	-	-	-	-	-	22706
1978	19824	-	-	-	-	-	-	-	-	-	-	-	-	19824
1979	12864	-	-	-	-	-	-	-	-	-	-	-	-	12864
1980	18577	-	-	-	-	-	-	-	-	-	-	-	-	18577
1981	13736	-	-	-	-	-	-	-	-	-	-	-	-	13736
1982	16655	-	-	-	-	-	-	-	-	-	-	-	-	16655
1983	23054	-	-	-	-	-	-	-	-	-	-	-	-	23054
1984	53532	-	-	-	-	-	-	-	-	-	-	-	-	53532
1985	167272	2600	-	-	-	-	-	-	-	-	-	-	-	169872
1986	199256	26000	-	-	-	-	-	-	-	-	-	-	-	225256
1987	108417	18889	-	-	-	-	-	-	-	-	-	-	-	127306
1988	115076	20225	-	-	-	-	-	-	-	-	-	-	-	135301
1989	88707	15123	-	-	-	-	-	-	-	-	-	-	-	103830
1990	74604	11807	-	-	-	-	-	-	-	-	-	-	-	86411
1991	73683	11000	-	-	-	-	-	-	-	-	-	-	-	84683
1992	91111	13337	-	-	-	-	-	-	-	-	-	-	-	104448
1993	199771	32645	-	-	-	-	-	-	-	-	-	-	-	232457
1994	380771	74400	-	2911	21146	-	-	-	-	-	-	-	-	479228
1995	529838	101987	30577	57084	174109	-	7969	2500	881	556	-	-	-	905501
1996	699161	119290	60681	52788	164957	19541	19664	-	46131	11978	-	-	22424	1220283
1997	860963	168900	44292	59987	220154	11179	8694	-	25149	6190	1500	-	19499	1426507
1998	743925	124049	35519	68136	197789	2437	12827	-	15971	7003	605	-	14863	1223131
1999	740640	157328	37010	55527	203381	2412	5871	-	19207	-	-	-	14057	1235433
2000	713500	163261	34968	68625	186035	8939	-	-	14096	3298	-	-	14749	1207201
2001	495036	109054	24038	34170	77693	6070	6439	-	12230	1588	-	-	9818	766136
2002	487233	113763	18998	32302	127197	1699	9392	-	3482	3017	-	1226	9486	807795
2003*	477573	122846	14144	27943	117910	1400	8678	-	9214	3371	-	-	6431	789510

***In 2003 the Norwegian catches were raised of 39433 to account for changes in percentages of water content.**

Table 7.5.1.1, cont. Total catch of Norwegian spring-spawning herring (tons) since 1972. Data provided by Working Group members.

Year	Norway	USSR/ Russia	Denmark	Faroes	Iceland	Ireland	Netherlands	Greenland	UK (Scotland)	Germany	France	Poland	Sweden	Total
2004	477076	115876	23111	42771	102787	11	17369	-	1869	4810	400	-	7986	794066
2005	580804	132099	28368	65071	156467	-	21517	-	-	17676	0	561	680	1003243
2006*	567237	120836	18449	63137	157474	4693	11625	-	12523	9958	80	-	2946	968958
2007	779089	162434	22911	64251	173621	6411	29764	4897	13244	6038	0	4333	0	1266993
2008	961603	193119	31128	74261	217602	7903	28155	3810	19737	8338	0	0	0	1545656
2009	1016675	210105	32320	85098	265479	10014	24021	3730	25477	14452	0	0	0	1687371
2010	871113	199472	26792	80281	205864	8061	26695	3453	24151	11133	0	0	0	1457015
2011	572641	144428	26740	53271	151074	5727	8348	3426	14045	13296	0	0	0	992997
2012	491005	118595	21754	36190	120956	4813	6237	1490	12310	11945	0	0	705	826000

*** Scotland and Northern Irland combined.**

Table 7.5.1.2. Norwegian spring spawning herring. Output from SALLOC for 2012 data.

Summary of Sampling by Country

AREA : IIa

Country	Sampled Catch	Official Catch	No. of samples	No. measured	No. aged	SOP %
Denmark	21753.83	21753.83	12	1523	586	100.19
Faroe Islands	30111.37	30589.85	7	694	682	99.97
Germany	1908.43	3361.25	2	679	94	99.27
Greenland	0.00	1490.00	0	0	0	0.00
Iceland	21469.00	53481.00	62	3219	1511	99.87
Ireland	4801.77	4801.77	2	242	100	100.08
Netherlands	0.00	6237.05	0	0	0	0.00
Norway	470120.00	470120.00	249	13425	6254	100.00
Russian federation	52574.00	52574.00	112	16760	1223	100.00
Scotland	0.00	12310.43	0	0	0	0.00
Sweden	0.00	705.00	0	0	0	0.00
Total IIa	602738.38	657424.19	446	36542	10450	100.00

Sum of Offical Catches : 657424.19
Unallocated Catch : 0.00
Discards : 0.00
Working Group Catch : 657424.19

AREA : IIb

Country	Sampled Catch	Official Catch	No. of samples	No. measured	No. aged	SOP %
Germany	8583.60	8583.60	8	3084	98	98.72
Norway	11266.00	11266.00	14	1472	94	100.00
Russian federation	64115.00	64115.00	58	10554	207	100.00
Total IIb	83964.59	83964.59	80	15110	399	99.87

Sum of Offical Catches : 83964.59
Unallocated Catch : 0.00
Discards : 0.00
Working Group Catch : 83964.59

AREA : IVa

Country	Sampled Catch	Official Catch	No. of samples	No. measured	No. aged	SOP %
Faroe Islands	10.88	10.88	2	186	182	99.98
Ireland	0.00	10.48	0	0	0	0.00
Norway	9546.00	9619.00	8	591	591	100.01
Total IVa	9556.88	9640.36	10	777	773	100.01

Sum of Offical Catches : 9640.36
Unallocated Catch : 0.00
Discards : 0.00
Working Group Catch : 9640.36

AREA : Va

Country	Sampled Catch	Official Catch	No. of samples	No. measured	No. aged	SOP %
Iceland	66374.00	67372.00	103	5329	2341	100.02
Total Va	66374.00	67372.00	103	5329	2341	100.02

Sum of Offical Catches : 67372.00
Unallocated Catch : 0.00
Discards : 0.00
Working Group Catch : 67372.00

AREA : Vb

Country	Sampled Catch	Official Catch	No. of samples	No. measured	No. aged	SOP %
Faroe Islands	5589.28	5589.28	7	679	661	99.97
Iceland	103.00	103.00	1	50	21	100.00
Total Vb	5692.28	5692.28	8	729	682	99.97

Sum of Offical Catches : 5692.28
Unallocated Catch : 0.00
Discards : 0.00
Working Group Catch : 5692.28

AREA : XIVa

Country	Sampled Catch	Official Catch	No. of samples	No. measured	No. aged	SOP %
Russian federation	1906.00	1906.00	2	840	123	100.00
Total XIVa	1906.00	1906.00	2	840	123	100.00

Sum of Offical Catches : 1906.00
Unallocated Catch : 0.00
Discards : 0.00
Working Group Catch : 1906.00

PERIOD : 1

Country	Sampled Catch	Official Catch	No. of samples	No. measured	No. aged	SOP %
Denmark	11480.55	11480.55	10	1309	491	99.68
Faroe Islands	0.00	478.48	0	0	0	0.00
Ireland	4801.77	4801.77	2	242	100	100.08
Norway	237534.00	237534.00	160	9929	2879	100.00
Russian federation	12335.00	12335.00	14	1811	193	100.00
Scotland	0.00	12310.43	0	0	0	0.00
Period Total	266151.31	278940.25	186	13291	3663	99.99

Sum of Offical Catches : 278940.25
Unallocated Catch : 0.00
Discards : 0.00
Working Group Catch : 278940.25

PERIOD : 2

Country	Sampled Catch	Official Catch	No. of samples	No. measured	No. aged	SOP %
Faroe Islands	4442.46	4442.46	4	402	394	100.06
Iceland	5934.00	5934.00	28	1519	597	100.00
Norway	836.00	898.00	2	100	100	100.00
Russian federation	64.00	64.00	14	1811	193	100.00
Period Total	11276.46	11338.46	48	3832	1284	100.02

Sum of Offical Catches : 11338.46
Unallocated Catch : 0.00
Discards : 0.00
Working Group Catch : 11338.46

PERIOD : 3

Country	Sampled Catch	Official Catch	No. of samples	No. measured	No. aged	SOP %
Faroe Islands	7714.12	7714.12	6	559	549	99.96
Germany	10492.03	10492.03	10	3763	192	98.82
Iceland	82012.00	82012.00	138	7079	3276	99.97
Norway	12426.00	12437.00	11	201	80	100.01
Russian federation	46462.00	46462.00	87	15354	689	100.02
Period Total	159106.16	159117.16	252	26956	4786	99.90

Sum of Offical Catches : 159117.16
Unallocated Catch : 0.00
Discards : 0.00
Working Group Catch : 159117.16

PERIOD : 4

Country	Sampled Catch	Official Catch	No. of samples	No. measured	No. aged	SOP %
Denmark	10273.28	10273.28	2	214	95	100.77
Faroe Islands	23554.94	23554.94	6	598	582	99.95
Germany	0.00	1452.82	0	0	0	0.00
Greenland	0.00	1490.00	0	0	0	0.00
Iceland	0.00	33010.00	0	0	0	0.00
Ireland	0.00	10.48	0	0	0	0.00
Netherlands	0.00	6237.05	0	0	0	0.00
Norway	240136.00	240136.00	98	5258	3880	100.03
Russian federation	59734.00	59734.00	57	9178	478	100.00
Sweden	0.00	705.00	0	0	0	0.00
Period Total	333698.22	376603.56	163	15248	5035	100.02

```
      Sum of Offical Catches :      376603.56
      Unallocated Catch :                0.00
     Discards          :                 0.00
      Working Group Catch :         376603.56
```

Total over all Areas and Periods

Country	Sampled Catch	Official Catch	No. of samples	No. measured	No. aged	SOP %
Denmark	21753.83	21753.83	12	1523	586	100.19
Faroe Islands	35711.52	36190.00	16	1559	1525	99.97
Germany	10492.03	11944.85	10	3763	192	98.82
Greenland	0.00	1490.00	0	0	0	0.00
Iceland	87946.00	120956.00	166	8598	3873	99.97
Ireland	4801.77	4812.25	2	242	100	100.08
Netherlands	0.00	6237.05	0	0	0	0.00
Norway	490932.00	491005.00	271	15488	6939	100.00
Russian federation	118595.00	118595.00	172	28154	1553	100.00
Scotland	0.00	12310.43	0	0	0	0.00
Sweden	0.00	705.00	0	0	0	0.00
Total for Stock	770232.13	825999.44	649	59327	14768	99.99

```
      Sum of Offical Catches :      825999.44
      Unallocated Catch :                0.00
     Discards          :                 0.00
      Working Group Catch :         825999.44
```

DETAILS OF DATA FILLING-IN

```
  Filling-in for record : (  2)   Scotland              1 IIa
Using Only
  >>  (  1)  Norway                 1 IIa

  Filling-in for record : (  5)   Faroe Islands         1 IIa
Using Only
  >>  (  1)  Norway                 1 IIa

  Filling-in for record : ( 12)   Norway                2 IVa
Using Only
  >>  (  8)  Norway                 2 IIa

  Filling-in for record : ( 23)   Norway                3 IVa
Using Only
  >>  ( 24)  Faroe Islands          3 IVa

  Filling-in for record : ( 31)   Germany               4 IIa
Using Only
  >>  ( 28)  Norway                 4 IIa

  Filling-in for record : ( 32)   Sweden                4 IIa
Using Only
  >>  ( 28)  Norway                 4 IIa

  Filling-in for record : ( 33)   Iceland               4 IIa
Using Only
  >>  ( 28)  Norway                 4 IIa

  Filling-in for record : ( 34)   Netherlands           4 IIa
Using Only
  >>  ( 28)  Norway                 4 IIa

  Filling-in for record : ( 38)   Ireland               4 IVa
Using Only
  >>  ( 24)  Faroe Islands          3 IVa

  Filling-in for record : ( 39)   Iceland               4 Va
Using Only
  >>  ( 37)  Russian federation     4 IIb

  Filling-in for record : ( 41)   Greenland             4 IIa
Using Only
  >>  ( 35)  Faroe Islands          4 IIa
```

Catch Numbers at Age by Area

For Periods 1 to 4

Ages	IIa	IIb	IVa	Va	Vb	XIVa	Total
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	2680.09	0.00	0.00	0.00	0.00	0.00	2680.09
2	11803.70	899.69	1.12	19.83	109.16	249.83	13083.32
3	189915.84	7978.17	810.74	9757.73	774.25	2393.72	211630.45
4	39684.97	4543.70	497.65	3240.27	1885.90	146.18	49998.68
5	87684.16	24167.85	1667.63	3267.27	2478.77	361.46	119627.15
6	232979.88	32965.13	4842.91	7620.95	3084.24	414.42	281907.53
7	168553.92	76553.34	2619.57	10878.89	3657.91	1065.92	263329.50
8	651582.00	52566.25	13217.22	25533.82	3701.06	1238.20	747838.56
9	235517.80	28229.51	2791.62	45317.38	2234.75	603.29	314694.34
10	285463.09	8056.13	4595.98	58721.65	815.16	250.12	357902.13
11	41320.90	1517.17	1.13	9954.79	186.20	128.36	53108.56
12	33841.55	2093.20	236.14	8607.80	154.05	49.19	44981.93
13	55326.20	1951.63	714.00	6246.38	26.10	9.01	64273.30
14	10816.72	165.00	78.00	1359.78	0.44	0.00	12419.94
15	3030.27	4.00	0.00	569.62	0.00	0.00	3603.89

Mean Weight at Age by Area (Kg)

For Periods 1 to 4

Ages	IIa	IIb	IVa	Va	Vb	XIVa	Total
0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1	0.0340	0.0000	0.0000	0.0000	0.0000	0.0000	0.0340
2	0.1114	0.3170	0.1830	0.3170	0.1810	0.0885	0.1260
3	0.2081	0.2242	0.1719	0.2765	0.2078	0.1571	0.2112
4	0.2674	0.3061	0.2141	0.3126	0.2194	0.3025	0.2716
5	0.2961	0.3262	0.2514	0.3276	0.2379	0.3264	0.3013
6	0.3036	0.3402	0.2567	0.3311	0.2814	0.3293	0.3076
7	0.3259	0.3409	0.3265	0.3372	0.3249	0.3494	0.3308
8	0.3327	0.3668	0.3109	0.3473	0.3413	0.3542	0.3353
9	0.3481	0.3725	0.3224	0.3534	0.3448	0.3728	0.3509
10	0.3512	0.3855	0.3192	0.3631	0.3513	0.3833	0.3536
11	0.3687	0.4020	0.3690	0.3717	0.3489	0.4024	0.3702
12	0.3886	0.3989	0.4282	0.3861	0.3728	0.4495	0.3888
13	0.3896	0.3993	0.3788	0.3834	0.2915	0.4020	0.3891
14	0.3810	0.3805	0.3780	0.3894	0.3224	0.0000	0.3819
15	0.3833	0.4100	0.0000	0.4144	0.0000	0.0000	0.3883

Mean Length at Age by Area (cm)

For Periods 1 to 4

Ages	IIa	IIb	IVa	Va	Vb	XIVa	Total
0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1	18.1000	0.0000	0.0000	0.0000	0.0000	0.0000	18.1000
2	23.7386	32.5000	26.0000	32.5000	26.0000	22.0000	24.3402
3	28.1304	29.3868	27.8940	29.1709	27.3036	26.5000	28.2033
4	30.7767	32.3800	29.8069	31.4881	28.2066	32.5000	30.8669
5	31.6355	32.6729	31.3984	32.4667	29.2103	32.9000	31.8181
6	32.0980	33.0327	31.3973	32.6183	30.9928	33.3000	32.1990
7	32.8906	33.3629	32.8902	33.0039	32.6059	33.9000	33.0327
8	33.1065	33.9010	32.8933	33.4871	33.2021	34.2000	33.1738
9	33.8153	34.4169	33.5991	33.8049	33.4080	34.7000	33.8647
10	33.9975	34.3559	33.5967	34.2927	33.6239	35.3000	34.0489
11	34.6729	35.3232	34.4900	34.7217	33.4424	36.4000	34.7004
12	35.3172	35.2436	35.9902	35.4369	34.2451	37.2000	35.3386
13	35.2499	34.7238	35.3000	35.3047	33.1523	36.3000	35.2391
14	35.5429	36.1000	36.0000	35.6200	34.4783	0.0000	35.5616
15	35.3089	38.0000	0.0000	36.8395	0.0000	0.0000	35.5538

Catch Numbers at Age by Area

For Period 1

Ages	IIa	IIb	IVa	Va	Vb	XIVa	Total
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	930.42	0.00	0.00	0.00	0.00	0.00	930.42
3	20008.41	0.00	804.00	0.00	0.00	0.00	20812.41
4	9072.30	0.00	492.00	0.00	0.00	0.00	9564.30
5	29311.30	0.00	1658.00	0.00	0.00	0.00	30969.30
6	100719.09	0.00	4805.00	0.00	0.00	0.00	105524.09
7	57020.76	0.00	2584.00	0.00	0.00	0.00	59604.76
8	274528.72	0.00	13077.00	0.00	0.00	0.00	287605.72
9	104198.52	0.00	2764.00	0.00	0.00	0.00	106962.52
10	166483.88	0.00	4551.00	0.00	0.00	0.00	171034.88
11	23762.88	0.00	0.00	0.00	0.00	0.00	23762.88
12	20017.39	0.00	235.00	0.00	0.00	0.00	20252.39
13	43214.44	0.00	714.00	0.00	0.00	0.00	43928.44
14	8411.79	0.00	78.00	0.00	0.00	0.00	8489.79
15	1792.19	0.00	0.00	0.00	0.00	0.00	1792.19

Mean Weight at Age by Area (Kg)

For Period 1

Ages	IIa	IIb	IVa	Va	Vb	XIVa	Total
0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	0.0817	0.0000	0.0000	0.0000	0.0000	0.0000	0.0817
3	0.1421	0.0000	0.1716	0.0000	0.0000	0.0000	0.1432
4	0.2044	0.0000	0.2135	0.0000	0.0000	0.0000	0.2049
5	0.2464	0.0000	0.2512	0.0000	0.0000	0.0000	0.2466
6	0.2714	0.0000	0.2566	0.0000	0.0000	0.0000	0.2707
7	0.2918	0.0000	0.3267	0.0000	0.0000	0.0000	0.2933
8	0.3101	0.0000	0.3110	0.0000	0.0000	0.0000	0.3102
9	0.3276	0.0000	0.3222	0.0000	0.0000	0.0000	0.3275
10	0.3443	0.0000	0.3191	0.0000	0.0000	0.0000	0.3436
11	0.3555	0.0000	0.0000	0.0000	0.0000	0.0000	0.3555
12	0.3873	0.0000	0.4286	0.0000	0.0000	0.0000	0.3878
13	0.3888	0.0000	0.3788	0.0000	0.0000	0.0000	0.3887
14	0.3730	0.0000	0.3780	0.0000	0.0000	0.0000	0.3730
15	0.3664	0.0000	0.0000	0.0000	0.0000	0.0000	0.3664

Mean Length at Age by Area (cm)

For Period 1

Ages	IIa	IIb	IVa	Va	Vb	XIVa	Total
0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	22.5000	0.0000	0.0000	0.0000	0.0000	0.0000	22.5000
3	25.9600	0.0000	27.9000	0.0000	0.0000	0.0000	26.0350
4	29.4399	0.0000	29.8000	0.0000	0.0000	0.0000	29.4584
5	30.8570	0.0000	31.4000	0.0000	0.0000	0.0000	30.8861
6	31.6522	0.0000	31.4000	0.0000	0.0000	0.0000	31.6407
7	32.4684	0.0000	32.9000	0.0000	0.0000	0.0000	32.4871
8	32.7858	0.0000	32.9000	0.0000	0.0000	0.0000	32.7910
9	33.5986	0.0000	33.6000	0.0000	0.0000	0.0000	33.5986
10	33.9365	0.0000	33.6000	0.0000	0.0000	0.0000	33.9276
11	34.3604	0.0000	0.0000	0.0000	0.0000	0.0000	34.3604
12	35.2374	0.0000	36.0000	0.0000	0.0000	0.0000	35.2462
13	35.2209	0.0000	35.3000	0.0000	0.0000	0.0000	35.2222
14	35.4000	0.0000	36.0000	0.0000	0.0000	0.0000	35.4055
15	35.5000	0.0000	0.0000	0.0000	0.0000	0.0000	35.5000

Catch Numbers at Age by Area

For Period 2

Ages	IIa	IIb	IVa	Va	Vb	XIVa	Total
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	192.87	0.00	0.00	338.25	43.73	0.00	574.85
4	186.77	0.00	0.00	228.82	1150.76	0.00	1566.35
5	313.50	0.00	0.00	229.69	1503.25	0.00	2046.44
6	1813.01	0.00	20.77	585.91	1000.25	0.00	3419.93
7	3712.67	0.00	10.38	803.27	441.34	0.00	4967.66
8	7003.58	0.00	119.48	1950.39	422.38	0.00	9495.82
9	3445.96	0.00	15.57	3296.62	371.82	0.00	7129.97
10	2967.54	0.00	41.53	3878.81	174.06	0.00	7061.94
11	584.85	0.00	0.00	595.70	35.56	0.00	1216.11
12	195.40	0.00	0.00	422.37	3.56	0.00	621.33
13	145.44	0.00	0.00	319.77	26.10	0.00	491.32
14	28.78	0.00	0.00	68.86	0.44	0.00	98.08
15	6.00	0.00	0.00	12.41	0.00	0.00	18.41

Mean Weight at Age by Area (Kg)

For Period 2

Ages	IIa	IIb	IVa	Va	Vb	XIVa	Total
0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
3	0.2405	0.0000	0.0000	0.2452	0.2095	0.0000	0.2409
4	0.2668	0.0000	0.0000	0.2753	0.1900	0.0000	0.2116
5	0.2708	0.0000	0.0000	0.2867	0.2036	0.0000	0.2232
6	0.2776	0.0000	0.2500	0.2896	0.2227	0.0000	0.2634
7	0.2972	0.0000	0.2850	0.2935	0.2482	0.0000	0.2922
8	0.3032	0.0000	0.2929	0.3015	0.2572	0.0000	0.3006
9	0.3122	0.0000	0.3324	0.3067	0.2664	0.0000	0.3073
10	0.3160	0.0000	0.3293	0.3153	0.2611	0.0000	0.3144
11	0.3178	0.0000	0.0000	0.3206	0.2318	0.0000	0.3167
12	0.3332	0.0000	0.0000	0.3353	0.3192	0.0000	0.3345
13	0.3335	0.0000	0.0000	0.3347	0.2915	0.0000	0.3321
14	0.3363	0.0000	0.0000	0.3406	0.3224	0.0000	0.3393
15	0.3637	0.0000	0.0000	0.3624	0.0000	0.0000	0.3628

Mean Length at Age by Area (cm)

For Period 2

Ages	IIa	IIb	IVa	Va	Vb	XIVa	Total
0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
3	29.8114	0.0000	0.0000	29.9337	27.9651	0.0000	29.7429
4	31.3871	0.0000	0.0000	31.7759	27.0240	0.0000	28.2385
5	31.6601	0.0000	0.0000	32.4558	27.9533	0.0000	29.0265
6	31.7995	0.0000	30.5000	32.6271	29.1004	0.0000	31.1440
7	32.6272	0.0000	31.0000	32.8533	30.5828	0.0000	32.4787
8	32.8916	0.0000	32.1000	33.3117	31.1049	0.0000	32.8885
9	33.5354	0.0000	33.4000	33.6075	31.5917	0.0000	33.4671
10	33.7238	0.0000	33.2000	34.0893	31.1814	0.0000	33.8588
11	33.9784	0.0000	0.0000	34.3785	29.5157	0.0000	34.0439
12	35.1176	0.0000	0.0000	35.1800	34.3080	0.0000	35.1554
13	35.0960	0.0000	0.0000	35.1519	33.1523	0.0000	35.0291
14	35.2394	0.0000	0.0000	35.4635	34.4783	0.0000	35.3934
15	36.6903	0.0000	0.0000	36.6226	0.0000	0.0000	36.6447

Catch Numbers at Age by Area

For Period 3

Ages	IIa	IIb	IVa	Va	Vb	XIVa	Total
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	3370.03	0.00	0.76	0.00	36.40	249.83	3657.01
3	36119.39	0.00	4.56	9249.42	219.42	2393.72	47986.51
4	3947.00	3072.51	3.82	2991.35	184.03	146.18	10344.90
5	9045.22	8826.00	6.51	2719.86	313.46	361.46	21272.51
6	16118.96	14249.18	11.59	6693.88	558.20	414.42	38046.23
7	27838.87	20812.61	17.03	8938.96	820.07	1065.92	59493.46
8	42539.92	19786.43	14.02	23080.18	675.34	1238.20	87334.09
9	32192.72	8381.45	8.14	41679.09	392.14	603.29	83256.83
10	27267.67	2015.40	2.33	54795.83	112.17	250.12	84443.52
11	5086.42	4.98	0.77	9344.53	36.95	128.36	14602.01
12	3001.70	0.00	0.77	8156.25	37.16	49.19	11245.07
13	1974.70	22.63	0.00	5926.60	0.00	9.01	7932.94
14	373.66	0.00	0.00	1290.92	0.00	0.00	1664.58
15	16.71	0.00	0.00	557.21	0.00	0.00	573.91

Mean Weight at Age by Area (Kg)

For Period 3

Ages	IIa	IIb	IVa	Va	Vb	XIVa	Total
0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	0.0885	0.0000	0.1830	0.0000	0.1830	0.0885	0.0895
3	0.1678	0.0000	0.2070	0.2786	0.2070	0.1571	0.1888
4	0.2963	0.3037	0.2700	0.3155	0.2700	0.3025	0.3036
5	0.3252	0.3403	0.2860	0.3321	0.2860	0.3264	0.3318
6	0.3365	0.3425	0.3000	0.3347	0.3000	0.3293	0.3378
7	0.3483	0.3449	0.3220	0.3409	0.3220	0.3494	0.3457
8	0.3525	0.3727	0.3370	0.3509	0.3370	0.3542	0.3565
9	0.3615	0.3780	0.3470	0.3570	0.3470	0.3728	0.3609
10	0.3640	0.3815	0.3560	0.3665	0.3560	0.3833	0.3661
11	0.3804	0.4580	0.3690	0.3749	0.3690	0.4024	0.3770
12	0.3988	0.0000	0.3560	0.3886	0.3560	0.4495	0.3915
13	0.3866	0.4440	0.0000	0.3860	0.0000	0.4020	0.3863
14	0.3907	0.0000	0.0000	0.3920	0.0000	0.0000	0.3917
15	0.4108	0.0000	0.0000	0.4156	0.0000	0.0000	0.4154

Mean Length at Age by Area (cm)

For Period 3

Ages	IIa	IIb	IVa	Va	Vb	XIVa	Total
0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	22.0000	0.0000	26.0000	0.0000	26.0000	22.0000	22.0406
3	26.7547	0.0000	27.1800	29.1388	27.1800	26.5000	27.2035
4	31.7552	32.4066	30.4100	31.4546	30.4100	32.5000	31.8479
5	32.3906	32.7522	31.1200	32.4404	31.1200	32.9000	32.5365
6	32.7951	33.0126	31.7400	32.5930	31.7400	33.3000	32.8307
7	33.4873	33.0759	32.6600	32.9544	32.6600	33.9000	33.2591
8	33.5992	34.0389	33.2500	33.4907	33.2500	34.2000	33.6759
9	33.9967	34.4212	33.6600	33.8132	33.6600	34.7000	33.9511
10	34.2152	34.4000	33.9900	34.3069	33.9900	35.3000	34.2820
11	35.3025	37.2500	34.4900	34.7408	34.4900	36.4000	34.9513
12	35.7894	0.0000	33.9800	35.4475	33.9800	37.2000	35.5415
13	35.4330	36.7500	0.0000	35.3130	0.0000	36.3000	35.3481
14	35.7984	0.0000	0.0000	35.6284	0.0000	0.0000	35.6665
15	36.7921	0.0000	0.0000	36.8443	0.0000	0.0000	36.8428

Catch Numbers at Age by Area

For Period 4

Ages	IIa	IIb	IVa	Va	Vb	XIVa	Total
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	2680.09	0.00	0.00	0.00	0.00	0.00	2680.09
2	7503.25	899.69	0.36	19.83	72.75	0.00	8495.89
3	133595.17	7978.17	2.18	170.06	511.10	0.00	142256.69
4	26478.90	1471.19	1.83	20.09	551.12	0.00	28523.12
5	49014.13	15341.85	3.12	317.72	662.07	0.00	65338.88
6	114328.82	18715.95	5.55	341.15	1525.79	0.00	134917.27
7	79981.65	55740.73	8.16	1136.66	2396.50	0.00	139263.69
8	327509.78	32779.82	6.72	503.25	2603.34	0.00	363402.91
9	95680.61	19848.06	3.90	341.66	1470.79	0.00	117345.02
10	88744.01	6040.73	1.12	47.02	528.93	0.00	95361.80
11	11886.75	1512.19	0.37	14.55	113.69	0.00	13527.55
12	10627.07	2093.20	0.37	29.17	113.33	0.00	12863.14
13	9991.62	1929.00	0.00	0.00	0.00	0.00	11920.62
14	2002.49	165.00	0.00	0.00	0.00	0.00	2167.49
15	1215.38	4.00	0.00	0.00	0.00	0.00	1219.38

Mean Weight at Age by Area (Kg)

For Period 4

Ages	IIa	IIb	IVa	Va	Vb	XIVa	Total
0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1	0.0340	0.0000	0.0000	0.0000	0.0000	0.0000	0.0340
2	0.1253	0.3170	0.1830	0.3170	0.1800	0.0000	0.1465
3	0.2289	0.2242	0.2070	0.2230	0.2080	0.0000	0.2285
4	0.2848	0.3110	0.2700	0.3130	0.2640	0.0000	0.2857
5	0.3206	0.3182	0.2860	0.3182	0.2930	0.0000	0.3198
6	0.3277	0.3385	0.3000	0.3332	0.3130	0.0000	0.3290
7	0.3438	0.3394	0.3220	0.3390	0.3400	0.0000	0.3419
8	0.3497	0.3633	0.3370	0.3639	0.3560	0.0000	0.3509
9	0.3673	0.3701	0.3470	0.3698	0.3640	0.0000	0.3677
10	0.3615	0.3868	0.3560	0.4033	0.3800	0.0000	0.3632
11	0.3924	0.4019	0.3690	0.4320	0.3790	0.0000	0.3934
12	0.3893	0.3989	0.3560	0.4345	0.3800	0.0000	0.3908
13	0.3941	0.3988	0.0000	0.0000	0.0000	0.0000	0.3949
14	0.4135	0.3805	0.0000	0.0000	0.0000	0.0000	0.4110
15	0.4080	0.4100	0.0000	0.0000	0.0000	0.0000	0.4080

Mean Length at Age by Area (cm)

For Period 4

Ages	IIa	IIb	IVa	Va	Vb	XIVa	Total
0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1	18.1000	0.0000	0.0000	0.0000	0.0000	0.0000	18.1000
2	24.6730	32.5000	26.0000	32.5000	26.0000	0.0000	25.5316
3	28.8249	29.3868	27.1800	29.4000	27.3000	0.0000	28.8516
4	31.0845	32.3245	30.4100	33.2000	29.9400	0.0000	31.1278
5	31.9616	32.6273	31.1200	32.7000	31.1600	0.0000	32.1133
6	32.3971	33.0480	31.7400	33.1000	31.9600	0.0000	32.4842
7	32.9960	33.4700	32.6600	33.5000	32.9600	0.0000	33.1892
8	33.3159	33.8178	33.2500	34.0000	33.5300	0.0000	33.3636
9	34.0004	34.4151	33.6600	34.7000	33.8000	0.0000	34.0700
10	34.0540	34.3412	33.9900	34.6000	34.3500	0.0000	34.0741
11	35.0623	35.3168	34.4900	36.5000	34.3300	0.0000	35.0861
12	35.3378	35.2436	33.9800	36.2000	34.3300	0.0000	35.3155
13	35.3411	34.7000	0.0000	0.0000	0.0000	0.0000	35.2373
14	36.1000	36.1000	0.0000	0.0000	0.0000	0.0000	36.1000
15	35.0000	38.0000	0.0000	0.0000	0.0000	0.0000	35.0098

Table 7.5.3.1. Norwegian spring spawning herring. Catch in numbers (thousands).

	AGE															
Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1950	5112600	2000000	600000	276200	184800	185500	547000	628600	79500	88600	109500	86900	194500	368300	66400	344300
1951	1635500	7607700	400000	6600	383800	172400	164400	515600	602000	77100	82700	103100	107600	253500	348000	352500
1952	13721600	9149700	1232900	39300	60500	602300	136300	204500	380200	377900	79200	85700	107700	106800	186500	564400
1953	5697200	5055000	581300	740100	46600	100900	355600	81900	110900	314100	394900	61700	91200	94100	98800	730400
1954	10675990	7071090	855400	266300	1435500	142900	236000	490300	128100	199800	440400	460700	88400	100600	133000	803200
1955	5175600	2871100	510100	93000	276400	2045100	114300	189600	274700	85300	193400	295600	203200	58700	84600	580600
1956	5363900	2023700	627100	116500	251600	314200	2555100	110000	203900	264200	130700	198300	272800	163300	63000	565100
1957	5001900	3290800	219500	23300	373300	153800	228500	1985300	72000	127300	182500	88400	121200	149300	131600	281400
1958	9666990	2798100	666400	17500	17900	110900	89300	194400	973500	70700	123000	200900	98700	77400	70900	255600
1959	17896280	198530	325500	15100	26800	25900	146600	114800	240700	1103800	88600	124300	198000	88500	77400	235900
1960	12884310	13580790	392500	121700	18200	28100	24400	96200	73300	203900	1163000	85200	129700	153500	56700	168900
1961	6207500	16075600	2884800	31200	8100	4100	15000	19400	61600	49200	136100	728100	49700	45000	63000	60100
1962	3693200	4081100	1041300	1843800	8000	3100	7200	20200	11900	59100	52600	117000	813500	44200	54700	152300
1963	4807000	2119200	2045300	760400	835800	5300	1800	3600	18300	9300	107700	92500	174100	923700	79600	185300
1964	3613000	2728300	220300	114600	399000	2045800	13700	1500	3000	24900	29300	95600	82400	153000	772800	336800
1965	2303000	3780900	2853600	89900	256200	571100	2199700	19500	14900	7400	19100	40000	100500	107800	138700	883100
1966	3926500	662800	1678000	2048700	26900	466600	1306000	2884500	37900	14300	17400	26200	11000	69100	72100	556700
1967	426800	9877100	70400	1392300	3254000	26600	421300	1132000	1720800	8900	5700	3500	8500	8900	17500	104400
1968	1783600	437000	388300	99100	1880500	1387400	14220	94000	134100	345100	2000	1100	830	2500	2600	17000
1969	561200	507100	141900	188200	800	8800	4700	700	11700	33600	36000	300	200	200	200	2400
1970	119300	529400	33200	6300	18600	600	3300	3300	1000	13400	26200	28100	300	100	200	2000
1971	30500	42900	85100	1820	1020	1240	360	1110	1130	360	4410	6910	5450	0	20	120
1972	347100	41000	20400	35376	3476	3583	2481	694	1486	198	0	494	593	593	0	0
1973	29300	3500	1700	2389	25200	651	1506	278	178	0	0	0	0	0	180	0
1974	65900	7800	3900	100	241	24505	257	196	0	0	0	0	0	0	0	0
1975	30600	3600	1800	3268	132	910	30667	5	2	0	0	0	0	0	0	0
1976	.20100	2400	1200	23248	5436	0	0	13086	0	0	0	0	0	0	0	0
1977	43000	6200	3100	22103	23595	336	0	419	10766	0	0	0	0	0	0	0
1978	20100	2400	1200	3019	12164	20315	870	0	620	5027	0	0	0	0	0	0
1979	32600	3800	1900	6352	1866	6865	11216	326	0	0	2534	0	0	0	0	0
1980	6900	800	400	6407	5814	2278	8165	15838	441	8	0	2688	0	0	0	0
1981	8300	1100	11900	4166	4591	8596	2200	4512	8280	345	103	114	964	0	0	0
1982	22600	1100	200	13817	7892	4507	6258	1960	5075	6047	121	37	37	121	0	0

Table 7.5.3.1. cont. Norwegian spring spawning herring. Catch in numbers (thousands).

	Age															
Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1983	127000	4680	1670	3183	21191	9521	6181	6823	1293	4598	7329	143	40	143	860	0
1984	33860	1700	2490	4483	5388	61543	18202	12638	15608	7215	16338	6478	0	0	0	1650
1985	28570	13150	207220	21500	15500	16500	130000	59000	55000	63000	10000	31000	50000	0	0	2640
1986	13810	1380	3090	539785	17594	14500	15500	105000	75000	42000	77000	19469	66000	80000	0	2470
1987	13850	6330	35770	19776	501393	18672	3502	7058	28000	12000	9500	4500	7834	6500	7000	450
1988	15490	2790	9110	62923	25059	550367	9452	3679	5964	14583	8872	2818	3356	2682	1560	540
1989	7120	1930	25200	2890	3623	5650	324290	3469	800	679	3297	1375	679	321	260	0
1990	1020	400	15540	18633	2658	11875	10854	226280	1289	1519	2036	2415	646	179	590	480
1991	100	3370	3330	8438	2780	1410	14698	8867	218851	2499	461	87	690	103	260	540
1992	1630	150	1340	12586	33100	4980	1193	11981	5748	225677	2483	639	247	1236	0	0
1993	6570	130	7240	28408	106866	87269	8625	3648	29603	18631	410110	0	0	0	0	0
1994	430	20	8100	32500	110090	363920	164800	15580	8140	37330	35660	645410	2830	460	100	2070
1995	0	0	1130	57590	346460	622810	637840	231090	15510	15850	69750	83740	911880	4070	250	450
1996	0	0	30140	34360	713620	1571000	940580	406280	103410	5680	7370	66090	17570	836550	0	0
1997	0	0	21820	130450	270950	1795780	1993620	761210	326490	60870	20020	32400	90520	19120	370330	300
1998	0	0	82891	70323	242365	368310	1760319	1263750	381482	129971	42502	25343	3478	112604	5633	108514
1999	0	0	5029	137626	35820	134813	429433	1604959	1164263	291394	106005	14524	40040	7202	88598	63983
2000	0	0	14395	84016	560379	34933	110719	404460	1299253	1045001	216980	71589	16260	22701	23321	71811
2001	0	0	2076	102293	160678	426822	38749	95991	296460	839136	507106	73673	23722	3505	3356	22164
2002	0	0	62031	198360	643161	255516	326495	29843	93530	264675	663059	339326	52922	12437	7000	10087
2003	0	3461	4524	75243	323958	730468	175878	167776	22866	74494	217108	567253	219097	38555	8111	6192
2004	125	1846	43800	24299	92300	429510	714433	111022	137940	26656	52467	169196	401564	210547	28028	11883
2005	0	442	20411	447788	94206	170547	643600	930309	121856	123291	37967	65289	139331	344822	126879	15697
2006	0	1968	45438	75824	729898	82107	171370	726041	772217	88701	77115	30339	57882	133665	142240	49128
2007	0	4475	8450	224636	366983	1804495	152916	242923	728836	511664	47215	25384	15316	24488	64755	58465
2008	0	39898	123949	36630	550274	670681	2295912	199592	256132	586583	369620	29633	36025	23775	25195	63176
2009	0	3468	113424	192641	149075	1193781	914748	1929631	142931	262037	423972	238174	45519	9337	10153	70538
2010	0	75981	61673	101948	209295	189784	1064866	711951	1421939	175010	180164	340781	179039	12558	11602	49773
2011	0	126972	249809	61706	104634	234330	210165	755382	543212	642787	90515	117230	136509	45082	6628	11638
2012	0	2680	13083	211630	49999	119627	281908	263330	747839	314694	357902	53109	44982	64273	12420	3604

Table 7.5.4.1. Norwegian spring spawning herring. Weight at age in the catch (kg).

	age															
Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1950	0.007	0.025	0.058	0.110	0.188	0.211	0.234	0.253	0.266	0.280	0.294	0.303	0.312	0.32	0.323	0.334
1951	0.009	0.029	0.068	0.130	0.222	0.249	0.276	0.298	0.314	0.330	0.346	0.357	0.368	0.377	0.381	0.394
1952	0.008	0.026	0.061	0.115	0.197	0.221	0.245	0.265	0.279	0.293	0.308	0.317	0.327	0.335	0.339	0.349
1953	0.008	0.027	0.063	0.120	0.205	0.230	0.255	0.275	0.290	0.305	0.320	0.330	0.34	0.347	0.351	0.363
1954	0.008	0.026	0.062	0.117	0.201	0.225	0.250	0.269	0.284	0.299	0.313	0.323	0.333	0.341	0.345	0.356
1955	0.008	0.027	0.063	0.119	0.204	0.229	0.254	0.274	0.289	0.304	0.318	0.328	0.338	0.346	0.350	0.362
1956	0.008	0.028	0.066	0.126	0.215	0.241	0.268	0.289	0.304	0.320	0.336	0.346	0.357	0.365	0.369	0.382
1957	0.008	0.028	0.066	0.127	0.216	0.243	0.269	0.290	0.306	0.322	0.338	0.348	0.359	0.367	0.371	0.384
1958	0.009	0.030	0.070	0.133	0.227	0.255	0.283	0.305	0.321	0.338	0.355	0.366	0.377	0.386	0.390	0.403
1959	0.009	0.030	0.071	0.135	0.231	0.259	0.287	0.310	0.327	0.344	0.360	0.372	0.383	0.392	0.397	0.409
1960	0.006	0.011	0.074	0.119	0.188	0.277	0.337	0.318	0.363	0.379	0.360	0.420	0.411	0.439	0.450	0.447
1961	0.006	0.010	0.045	0.087	0.159	0.276	0.322	0.372	0.363	0.393	0.407	0.397	0.422	0.447	0.465	0.452
1962	0.009	0.023	0.055	0.085	0.148	0.288	0.333	0.360	0.352	0.350	0.374	0.384	0.374	0.394	0.399	0.414
1963	0.008	0.026	0.047	0.098	0.171	0.275	0.268	0.323	0.329	0.336	0.341	0.358	0.385	0.353	0.381	0.386
1964	0.009	0.024	0.059	0.139	0.219	0.239	0.298	0.295	0.339	0.350	0.358	0.351	0.367	0.375	0.372	0.433
1965	0.009	0.016	0.048	0.089	0.217	0.234	0.262	0.331	0.360	0.367	0.386	0.395	0.393	0.404	0.401	0.431
1966	0.008	0.017	0.040	0.063	0.246	0.260	0.265	0.301	0.410	0.425	0.456	0.460	0.467	0.446	0.459	0.472
1967	0.009	0.015	0.036	0.066	0.093	0.305	0.305	0.310	0.333	0.359	0.413	0.446	0.401	0.408	0.439	0.430
1968	0.010	0.027	0.049	0.075	0.108	0.158	0.375	0.383	0.364	0.382	0.441	0.410		0.517	0.491	0.485
1969	0.009	0.021	0.047	0.072		0.152	0.296		0.329	0.329	0.341					0.429
1970	0.008	0.058	0.085	0.105	0.171		0.216	0.277	0.298	0.304	0.305	0.309				0.376
1971	0.011	0.053	0.121	0.177	0.216	0.250		0.305	0.333		0.366	0.377	0.388			
1972	0.011	0.029	0.062	0.103	0.154	0.215	0.258		0.322							
1973	0.006	0.053	0.106	0.161	0.213		0.255									
1974	0.006	0.055	0.117			0.249										
1975	0.009	0.079	0.169	0.241			0.381									
1976	0.007	0.062	0.132	0.189	0.250			0.323								
1977	0.011	0.091	0.193	0.316	0.350				0.511							
1978	0.012	0.100	0.210	0.274	0.424	0.454				0.613						
1979	0.010	0.088	0.181	0.293	0.359	0.416	0.436				0.553					
1980	0.012			0.266	0.399	0.449	0.460	0.485				0.608				
1981	0.010	0.082	0.163	0.196	0.291	0.341	0.368	0.380	0.397							
1982	0.010	0.087	0.159	0.256	0.312	0.378	0.415	0.435	0.449	0.448						

Table 7.5.4.1. cont. Norwegian spring spawning herring. Weight at age in the catch (kg).

	age														
Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1983	0.011	0.090	0.165	0.217	0.265	0.337	0.378	0.410	0.426	0.435	0.444					
1984	0.009	0.047	0.145	0.218	0.262	0.325	0.346	0.381	0.400	0.413	0.405	0.426				0.415
1985	0.009	0.022	0.022	0.214	0.277	0.295	0.338	0.360	0.381	0.397	0.409	0.417	0.435			0.435
1986	0.007	0.077	0.097	0.055	0.249	0.294	0.312	0.352	0.374	0.398	0.402	0.401	0.410	0.410		0.410
1987	0.010	0.075	0.091	0.124	0.173	0.253	0.232	0.312	0.328	0.349	0.353	0.370	0.385	0.385	0.385	
1988	0.008	0.062	0.075	0.124	0.154	0.194	0.241	0.265	0.304	0.305	0.317	0.308	0.334	0.334	0.334	
1989	0.010	0.060	0.204	0.188	0.264	0.260	0.282	0.306			0.422	0.364				
1990	0.007		0.102	0.230	0.239	0.266	0.305	0.308	0.376	0.407	0.412	0.424				
1991		0.015	0.104	0.208	0.250	0.288	0.312	0.316	0.330	0.344						
1992	0.007		0.103	0.191	0.233	0.304	0.337	0.365	0.361	0.371	0.403			0.404		
1993	0.007		0.106	0.153	0.243	0.282	0.320	0.330	0.365	0.373	0.379					
1994			0.102	0.194	0.239	0.280	0.317	0.328	0.356	0.372	0.390	0.379	0.399	0.403		
1995			0.102	0.153	0.192	0.234	0.283	0.328	0.349	0.356	0.374	0.366	0.393	0.387		
1996			0.136	0.136	0.168	0.206	0.262	0.309	0.337	0.366	0.360	0.361	0.367	0.379		
1997			0.089	0.167	0.184	0.207	0.232	0.277	0.305	0.331	0.328	0.344	0.343	0.397	0.357	
1998			0.111	0.150	0.216	0.221	0.249	0.277	0.316	0.338	0.374	0.372	0.366	0.396	0.377	0.406
1999			0.096	0.173	0.228	0.262	0.274	0.292	0.307	0.335	0.362	0.371	0.399	0.396	0.400	0.404
2000			0.124	0.175	0.222	0.242	0.289	0.303	0.310	0.328	0.349	0.383	0.411	0.410	0.419	0.409
2001			0.105	0.166	0.214	0.252	0.268	0.305	0.308	0.322	0.337	0.363	0.353	0.378	0.400	0.427
2002			0.056	0.128	0.198	0.255	0.281	0.303	0.322	0.323	0.334	0.345	0.369	0.407	0.410	0.435
2003		0.062	0.068	0.169	0.218	0.257	0.288	0.316	0.323	0.348	0.354	0.351	0.363	0.372	0.376	0.429
2004	0.022	0.066	0.143	0.18	0.227	0.26	0.29	0.323	0.355	0.375	0.383	0.399	0.395	0.405	0.429	0.439
2005		0.092	0.106	0.181	0.235	0.266	0.290	0.315	0.344	0.367	0.384	0.372	0.384	0.398	0.402	0.413
2006		0.055	0.102	0.171	0.238	0.268	0.292	0.311	0.330	0.365	0.374	0.376	0.388	0.396	0.398	0.407
2007	0.000	0.074	0.137	0.162	0.228	0.271	0.316	0.332	0.342	0.358	0.361	0.381	0.390	0.400	0.405	0.399
2008	0.000	0.026	0.106	0.145	0.209	0.254	0.296	0.318	0.341	0.353	0.363	0.367	0.395	0.396	0.386	0.413
2009	0	0.040	0.156	0.184	0.220	0.251	0.291	0.311	0.338	0.347	0.363	0.375	0.382	0.375	0.375	0.387
2010	0	0.059	0.107	0.177	0.218	0.261	0.279	0.311	0.325	0.343	0.362	0.370	0.388	0.391	0.376	0.441
2011	0	0.011	0.098	0.200	0.257	0.273	0.300	0.316	0.340	0.348	0.365	0.371	0.387	0.374	0.403	0.401
2012	0	0.034	0.126	0.211	0.272	0.301	0.308	0.331	0.335	0.351	0.354	0.370	0.389	0.389	0.382	0.388

Table 7.5.4.2. Norwegian spring spawning herring. Weight at age in the stock (kg).

	AGE															
Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1950	0.001	0.008	0.047	0.100	0.204	0.230	0.255	0.275	0.290	0.305	0.315	0.325	0.330	0.340	0.345	0.364
1951	0.001	0.008	0.047	0.100	0.204	0.230	0.255	0.275	0.290	0.305	0.315	0.325	0.330	0.340	0.345	0.364
1952	0.001	0.008	0.047	0.100	0.204	0.230	0.255	0.275	0.290	0.305	0.315	0.325	0.330	0.340	0.345	0.364
1953	0.001	0.008	0.047	0.100	0.204	0.230	0.255	0.275	0.290	0.305	0.315	0.325	0.330	0.340	0.345	0.364
1954	0.001	0.008	0.047	0.100	0.204	0.230	0.255	0.275	0.290	0.305	0.315	0.325	0.330	0.340	0.345	0.364
1955	0.001	0.008	0.047	0.100	0.195	0.213	0.260	0.275	0.290	0.305	0.315	0.325	0.330	0.340	0.345	0.364
1956	0.001	0.008	0.047	0.100	0.205	0.230	0.249	0.275	0.290	0.305	0.315	0.325	0.330	0.340	0.345	0.364
1957	0.001	0.008	0.047	0.100	0.136	0.228	0.255	0.262	0.290	0.305	0.315	0.325	0.330	0.340	0.345	0.364
1958	0.001	0.008	0.047	0.100	0.204	0.242	0.292	0.295	0.293	0.305	0.315	0.330	0.340	0.345	0.352	0.363
1959	0.001	0.008	0.047	0.100	0.204	0.252	0.260	0.290	0.300	0.305	0.315	0.325	0.330	0.340	0.345	0.358
1960	0.001	0.008	0.047	0.100	0.204	0.270	0.291	0.293	0.321	0.318	0.320	0.344	0.349	0.370	0.379	0.378
1961	0.001	0.008	0.047	0.100	0.232	0.250	0.292	0.302	0.304	0.323	0.322	0.321	0.344	0.357	0.363	0.368
1962	0.001	0.008	0.047	0.100	0.219	0.291	0.300	0.316	0.324	0.326	0.335	0.338	0.334	0.347	0.354	0.358
1963	0.001	0.008	0.047	0.100	0.185	0.253	0.294	0.312	0.329	0.327	0.334	0.341	0.349	0.341	0.358	0.375
1964	0.001	0.008	0.047	0.100	0.194	0.213	0.264	0.317	0.363	0.353	0.349	0.354	0.357	0.359	0.365	0.402
1965	0.001	0.008	0.047	0.100	0.186	0.199	0.236	0.260	0.363	0.350	0.370	0.360	0.378	0.387	0.390	0.394
1966	0.001	0.008	0.047	0.100	0.185	0.219	0.222	0.249	0.306	0.354	0.377	0.391	0.379	0.378	0.361	0.383
1967	0.001	0.008	0.047	0.100	0.180	0.228	0.269	0.270	0.294	0.324	0.420	0.430	0.366	0.368	0.433	0.414
1968	0.001	0.008	0.047	0.100	0.115	0.206	0.266	0.275	0.274	0.285	0.350	0.325	0.363	0.408	0.388	0.378
1969	0.001	0.008	0.047	0.100	0.115	0.145	0.270	0.300	0.306	0.308	0.318	0.340	0.368	0.360	0.393	0.397
1970	0.001	0.008	0.047	0.100	0.209	0.272	0.230	0.295	0.317	0.323	0.325	0.329	0.380	0.370	0.380	0.391
1971	0.001	0.015	0.080	0.100	0.190	0.225	0.250	0.275	0.290	0.310	0.325	0.335	0.345	0.355	0.365	0.390
1972	0.001	0.010	0.070	0.150	0.150	0.140	0.210	0.240	0.270	0.300	0.325	0.335	0.345	0.355	0.365	0.390
1973	0.001	0.010	0.085	0.170	0.259	0.342	0.384	0.409	0.404	0.461	0.520	0.534	0.500	0.500	0.500	0.500
1974	0.001	0.010	0.085	0.170	0.259	0.342	0.384	0.409	0.444	0.461	0.520	0.543	0.482	0.482	0.482	0.482
1975	0.001	0.010	0.085	0.181	0.259	0.342	0.384	0.409	0.444	0.461	0.520	0.543	0.482	0.482	0.482	0.482
1976	0.001	0.010	0.085	0.181	0.259	0.342	0.384	0.409	0.444	0.461	0.520	0.543	0.482	0.482	0.482	0.482
1977	0.001	0.010	0.085	0.181	0.259	0.343	0.384	0.409	0.444	0.461	0.520	0.543	0.482	0.482	0.482	0.482
1978	0.001	0.010	0.085	0.180	0.294	0.326	0.371	0.409	0.461	0.476	0.520	0.543	0.500	0.500	0.500	0.500
1979	0.001	0.010	0.085	0.178	0.232	0.359	0.385	0.420	0.444	0.505	0.520	0.551	0.500	0.500	0.500	0.500
1980	0.001	0.010	0.085	0.175	0.283	0.347	0.402	0.421	0.465	0.465	0.520	0.534	0.500	0.500	0.500	0.500
1981	0.001	0.010	0.085	0.170	0.224	0.336	0.378	0.387	0.408	0.397	0.520	0.543	0.512	0.512	0.512	0.512
1982	0.001	0.010	0.085	0.170	0.204	0.303	0.355	0.383	0.395	0.413	0.453	0.468	0.506	0.506	0.506	0.506

Table 7.5.4.2. cont. Norwegian spring spawning herring. Weight at age in the stock (kg).

	age														
Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1983	0.001	0.010	0.085	0.155	0.249	0.304	0.368	0.404	0.424	0.437	0.436	0.493	0.495	0.495	0.495	0.495
1984	0.001	0.010	0.085	0.140	0.204	0.295	0.338	0.376	0.395	0.407	0.413	0.422	0.437	0.437	0.437	0.437
1985	0.001	0.010	0.085	0.148	0.234	0.265	0.312	0.346	0.370	0.395	0.397	0.428	0.428	0.428	0.428	0.428
1986	0.001	0.010	0.085	0.054	0.206	0.265	0.289	0.339	0.368	0.391	0.382	0.388	0.395	0.395	0.395	0.395
1987	0.001	0.010	0.055	0.090	0.143	0.241	0.279	0.299	0.316	0.342	0.343	0.362	0.376	0.376	0.376	0.376
1988	0.001	0.015	0.050	0.098	0.135	0.197	0.277	0.315	0.339	0.343	0.359	0.365	0.376	0.376	0.376	0.376
1989	0.001	0.015	0.100	0.154	0.175	0.209	0.252	0.305	0.367	0.377	0.359	0.395	0.396	0.396	0.396	0.396
1990	0.001	0.008	0.048	0.219	0.198	0.258	0.288	0.309	0.428	0.370	0.403	0.387	0.440	0.440	0.440	0.44
1991	0.001	0.011	0.037	0.147	0.210	0.244	0.300	0.324	0.336	0.343	0.382	0.366	0.425	0.425	0.425	0.425
1992	0.001	0.007	0.030	0.128	0.224	0.296	0.327	0.355	0.345	0.367	0.341	0.361	0.430	0.470	0.470	0.46
1993	0.001	0.008	0.025	0.081	0.201	0.265	0.323	0.354	0.358	0.381	0.369	0.396	0.393	0.374	0.403	0.4
1994	0.001	0.010	0.025	0.075	0.151	0.254	0.318	0.371	0.347	0.412	0.382	0.407	0.410	0.410	0.410	0.41
1995	0.001	0.018	0.025	0.066	0.138	0.230	0.296	0.346	0.388	0.363	0.409	0.414	0.422	0.410	0.410	0.426
1996	0.001	0.018	0.025	0.076	0.118	0.188	0.261	0.316	0.346	0.374	0.390	0.390	0.384	0.398	0.398	0.398
1997	0.001	0.018	0.025	0.096	0.118	0.174	0.229	0.286	0.323	0.370	0.378	0.386	0.360	0.393	0.391	0.391
1998	0.001	0.018	0.025	0.074	0.147	0.174	0.217	0.242	0.278	0.304	0.310	0.359	0.340	0.344	0.385	0.369
1999	0.001	0.018	0.025	0.102	0.150	0.223	0.240	0.264	0.283	0.315	0.345	0.386	0.386	0.386	0.382	0.395
2000	0.001	0.018	0.025	0.119	0.178	0.225	0.271	0.285	0.298	0.311	0.339	0.390	0.398	0.406	0.414	0.427
2001	0.001	0.018	0.025	0.075	0.178	0.238	0.247	0.296	0.307	0.314	0.328	0.351	0.376	0.406	0.414	0.425
2002	0.001	0.010	0.023	0.057	0.177	0.241	0.275	0.302	0.311	0.314	0.328	0.341	0.372	0.405	0.415	0.438
2003	0.001	0.010	0.055	0.098	0.159	0.211	0.272	0.305	0.292	0.331	0.337	0.347	0.356	0.381	0.414	0.433
2004	0.001	0.010	0.055	0.106	0.149	0.212	0.241	0.279	0.302	0.337	0.354	0.355	0.360	0.371	0.400	0.429
2005	0.001	0.010	0.046	0.112	0.156	0.234	0.267	0.295	0.330	0.363	0.377	0.414	0.406	0.308	0.420	0.452
2006	0.001	0.010	0.042	0.107	0.179	0.232	0.272	0.297	0.318	0.371	0.365	0.393	0.395	0.399	0.415	0.428
2007	0.001	0.010	0.036	0.086	0.155	0.226	0.265	0.312	0.310	0.364	0.384	0.352	0.386	0.304	0.420	0.412
2008**	0.001	0.010	0.044	0.077	0.146	0.212	0.269	0.289	0.327	0.351	0.358	0.372	0.411	0.353	0.389	0.393
2009***	0.001	0.010	0.044	0.077	0.141	0.215	0.270	0.306	0.336	0.346	0.364	0.369	0.411	0.353	0.389	0.393
2010****	0.001	0.01	0.044	0.077	0.188	0.22	0.251	0.286	0.308	0.333	0.344	0.354	0.373	0.353	0.389	0.393
2011	0.001	0.01	0.044	0.118	0.185	0.209	0.246	0.277	0.310	0.322	0.339	0.349	0.364	0.363	0.389	0.393
2012	0.001	0.01	0.044	0.138	0.185	0.256	0.273	0.290	0.305	0.330	0.342	0.361	0.390	0.377	0.389	0.393
2013	0.001	0.01	0.044	0.138	0.204	0.267	0.305	0.309	0.320	0.328	0.346	0.350	0.390	0.377	0.389	0.393

**** mean weight at ages 11 and 13 are mean of 5 previous years at the same age. These age groups were not present in the catches of the wintering survey from which the stock weight are derived.**

***** derived from catch data from the wintering area north of 69°N during December 2008 – January 2009 for age groups 4-11.**

******derived from catch data from the wintering area north of 69°N during January 2010 for age groups 4-12**

Table 7.5.7.4.1. Norwegian spring-spawning herring. Acoustic estimates (billion individuals) of immature herring in the Barents Sea in May/June. No survey in 2003, 1990-2002. See footnotes. Shaded data are not used in the TASACS assessment. ***Survey 4.***

	survey 4		age		
Year	1	2	3	4	5
1991	24.3	5.2			
1992	32.6	14	5.7		
1993	102.7	25.8	1.5		
1994	6.6	59.2	18	1.7	
1995	0.5	7.7	8	1.1	
1996[1]	0.1	0.25	1.8	0.6	0.03
1997[2]	2.6	0.04	0.4	0.35	0.05
1998	9.5	4.7	0.01	0.01	0
1999	49.5	4.9	0	0	0
2000	105.4	27.9	0	0	0
2001	0.3	7.6	8.8	0	0
2002	0.5	3.9	0	0	0
2003[3]					
2004[3]					
2005	23.3	4.5	2.5	0.4	0.3
2006	3.7	35.0	5.3	0.87	0
2007	2.1	3.7	12.5	1.9	0
2008[4]	0.043	0.38	0.2	0.28	0
2009	0.19	0.47	0.67	0.39	0.41
2010	7.724	1.966	0.091	0	0
2011	0.6	3.6	0.02	0	0
2012	0.370	0.120	0	0	0
2013	0.036	1.912	0.377	0.024	

[1] **Average of Norwegian and Russian estimates**

[2] **Combination of Norwegian and Russian estimates as described in 1998 WG report, since then only Russian estimates**

[3] **No surveys**

[4] **Not a full survey**

Table 7.5.7.4.2. Norwegian spring spawning herring. Estimates from the international acoustic surveys on the feeding areas in the Norwegian Sea in May. Numbers in millions. Biomass in thousands. Biomass in thousands. Shaded data are not used in the TASACS assessment. ***Survey 5.***

	survey 5						Age									Total
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Total	Biomass
1996	0	0	4114	22461	13244	4916	2045	424	14	7	155	0	3134			50514	8532
1997	0	0	1169	3599	18867	13546	2473	1771	178	77	288	190	60	2697		44915	9435
1998	24	1404	367	1099	4410	16378	10160	2059	804	183	0	0	35	0	492	37415	8004
1999	0	215	2191	322	965	3067	11763	6077	853	258	5	14	0	158	128	26016	6299
2000	0	157	1353	2783	92	384	1302	7194	5344	1689	271	0	114	0	75	20758	6001
2001	0	1540	8312	1430	1463	179	204	3215	5433	1220	94	178	0	0	6	23274	3937
2002	0	677	6343	9619	1418	779	375	847	1941	2500	1423	61	78	28	0	26089	4628
2003	32073	8115	6561	9985	9961	1499	732	146	228	1865	2359	1769		287	0	75580	6653
2004	0	13735	1543	5227	12571	10710	1075	580	76	313	362	1294	1120	10	88	48704	7687
2005	0	1293	19679	1353	1765	6205	5371	651	388	139	262	526	1003	364	115	39114	5109
2006	0	19	306	14560	1396	2011	6521	6978	679	713	173	407	921	618	243	35545	9100
2007	0	411	2889	5877	20292	1260	1992	6780	5582	647	488	372	403	1048	1010	49051	12161
2008	0	1193	587	8332	8270	16345	1381	1920	3958	2500	416	242	159	217	408	45928	9996
2009	0	410	2316	2314	13545	8937	12025	1335	1334	2696	1488	208	175	65	232	47080	10406
2010	81	364	1195	3329	2156	8282	4146	4519	390	513	804	331	45	17	25	26857	5777
2011	0	1058	1576	1753	4550	2692	8693	2879	4830	572	898	837	281	13	34	30666	7298
2012	0	1588	2995	415	844	1835	2321	4346	1890	2338	329	615	344	112	54	20026	4629
2013	0	395	653	2900	496	1120	1923	2794	4311	2600	1782	538	573	209	62	20356	5291

Table 7.5.7.5.1. Norwegian spring-spawning herring. Acoustic estimates (billion individuals) of immature herring in the Barents Sea in August-October. Data in black boxes used in the assessment. *Survey 6.*

survey 6			
	Age		
Year	1	2	3
2000	14.7	11.5	0
2001	0.5	10.5	1.7
2002	1.3	0	0
2003	99.9	4.3	2.5
2004	14.3	36.5	0.9
2005	46.4	16.1	7.0
2006	1.6	5.5	1.3
2007	3.9	2.6	6.3
2008	0.03	1.62	3.99
2009	1.5	0.4	
2010	1.0	0.3	
2011	0.10	1.50	0.01
2012	2.0	1.1	

Table 7.5.7.5.2. Norwegian spring-spawning herring. Abundance indices for 0-group herring since 1980 in the Barents Sea, August-October. This index has been recalculated since 2006. Data in shaded cells are not used in the assessment *Survey 7***.**

survey 7	
Year	Abundance index
1980	4
1981	3
1982	202
1983	40557
1984	6313
1985	7237
1986	7
1987	2
1988	8686
1989	4196
1990	9508
1991	81175
1992	37183
1993	61508
1994	14884
1995	1308
1996	57169
1997	45808
1998	79492
1999	15931
2000	49614
2001	844
2002	23354
2003	28579
2004	133350
2005	26332
2006	66819
2007	22481
2008	15727
2009	18916
2010	20367
2011	13674
2012	26480

Table 7.5.7.6.1. Norwegian Spring-spawning herring. The indices for herring larvae on the Norwegian shelf for the period 1981-2007 ($N*10^{-12}$). Data in shaded cells are not used in the assessment. ***Survey 8.***

survey 8		
Year	Index1	Index 2
1981	0.3	
1982	0.7	
1983	2.5	
1984	1.4	
1985	2.3	
1986	1	
1987	1.3	4
1988	9.2	25.5
1989	13.4	28.7
1990	18.3	29.2
1991	8.6	23.5
1992	6.3	27.8
1993	24.7	78
1994	19.5	48.6
1995	18.2	36.3
1996	27.7	81.7
1997	66.6	147.5
1998	42.4	138.6
1999	19.9	73
2000	19.8	89.4
2001	40.7	135.9
2002	27.1	138.6
2003*	3.7	18.8
2004	56.4	215.1
2005	73.91	196.7
2006	98.9	389.0
2007**	90.6	
2008	107.9	393.3
2009	8.4	53.8
2010	42.7	140.2
2011	73.4	192.1
2012	65.6	224.4
2013	71.6	345.3

Index 1. The total number of herring larvae found during the cruise.

Index 2. Back-calculated number of newly hatched larvae with 10% daily moratlity. The larval age is estimated from the duration of the yolksac stages and the size of the larvae.

*** Poor weather conditions and survey was late in April**

**** only representative for the area 62-66°N**

Table 7.7.5.1. Norwegian Spring-spawning herring. Mature at age. The time series was provided by WKHERMAT in 2010 and are used in the assessment since 2010.

	age															
Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1950	0	0	0	0	0.2	0.8	1	1	1	1	1	1	1	1	1	1
1951	0	0	0	0	0.2	0.8	1	1	1	1	1	1	1	1	1	1
1952	0	0	0	0	0.1	0.6	1	1	1	1	1	1	1	1	1	1
1953	0	0	0	0	0.3	0.4	0.9	1	1	1	1	1	1	1	1	1
1954	0	0	0	0	0.1	0.7	0.9	1	1	1	1	1	1	1	1	1
1955	0	0	0	0.1	0.4	0.4	1	1	1	1	1	1	1	1	1	1
1956	0	0	0	0	0.5	0.7	0.6	1	1	1	1	1	1	1	1	1
1957	0	0	0	0	0.3	0.8	0.8	0.7	1	1	1	1	1	1	1	1
1958	0	0	0	0	0.3	0.5	0.9	0.9	1	1	1	1	1	1	1	1
1959	0	0	0	0	0.7	0.8	1	0.9	1	1	1	1	1	1	1	1
1960	0	0	0	0	0.3	0.9	0.9	1	1	1	1	1	1	1	1	1
1961	0	0	0	0	0.1	0.8	1	0.9	1	1	1	1	1	1	1	1
1962	0	0	0	0	0.1	0.7	1	1	1	1	1	1	1	1	1	1
1963	0	0	0	0	0.1	0.4	1	1	1	1	1	1	1	1	1	1
1964	0	0	0	0	0.1	0.4	0.8	1	1	1	1	1	1	1	1	1
1965	0	0	0	0	0.5	0.4	0.9	0.8	1	1	1	1	1	1	1	1
1966	0	0	0	0	0.5	0.7	0.9	1	1	1	1	1	1	1	1	1
1967	0	0	0	0	0.3	0.8	1	1	1	1	1	1	1	1	1	1
1968	0	0	0	0	0	0.7	0.9	1	1	1	1	1	1	1	1	1
1969	0	0	0	0.1	0.2	0.3	1	1	1	1	1	1	1	1	1	1
1970	0	0	0	0	0.4	0.3	0.4	1	1	1	1	1	1	1	1	1
1971	0	0	0	0	0.1	0.7	1	1	1	1	1	1	1	1	1	1
1972	0	0	0	0	0.4	0.3	1	1	1	1	1	1	1	1	1	1
1973	0	0	0	0.1	0.6	1	1	1	1	1	1	1	1	1	1	1
1974	0	0	0	0	0.6	0.9	1	1	1	1	1	1	1	1	1	1
1975	0	0	0	0.1	0.5	0.9	1	1	1	1	1	1	1	1	1	1
1976	0	0	0	0.1	0.9	0.9	1	1	1	1	1	1	1	1	1	1
1977	0	0	0	0.3	0.8	1	1	1	1	1	1	1	1	1	1	1
1978	0	0	0	0.2	0.9	1	1	1	1	1	1	1	1	1	1	1
1979	0	0	0	0.1	0.9	1	1	1	1	1	1	1	1	1	1	1
1980	0	0	0	0.1	0.9	1	1	1	1	1	1	1	1	1	1	1
1981	0	0	0	0.1	1	1	1	1	1	1	1	1	1	1	1	1
1982	0	0	0	0.1	0.8	1	1	1	1	1	1	1	1	1	1	1
1983	0	0	0	0.1	0.9	1	1	1	1	1	1	1	1	1	1	1
1984	0	0	0	0.1	0.7	1	1	1	1	1	1	1	1	1	1	1
1985	0	0	0	0.1	0.8	0.9	1	1	1	1	1	1	1	1	1	1
1986	0	0	0	0	0.5	0.9	0.9	1	1	1	1	1	1	1	1	1
1987	0	0	0	0	0.1	0.8	0.9	0.9	1	1	1	1	1	1	1	1
1988	0	0	0	0	0.2	0.7	0.9	1	1	1	1	1	1	1	1	1
1989	0	0	0	0	0.4	0.8	1	1	1	1	1	1	1	1	1	1
1990	0	0	0	0.2	0.5	0.9	1	1	1	1	1	1	1	1	1	1
1991	0	0	0	0	0.9	0.9	1	1	1	1	1	1	1	1	1	1
1992	0	0	0	0	0.8	1	1	1	1	1	1	1	1	1	1	1
1993	0	0	0	0	0.5	1	1	1	1	1	1	1	1	1	1	1
1994	0	0	0	0	0.1	0.9	1	1	1	1	1	1	1	1	1	1
1995	0	0	0	0	0	0.6	1	1	1	1	1	1	1	1	1	1
1996	0	0	0	0	0	0.5	0.9	1	1	1	1	1	1	1	1	1
1997	0	0	0	0.1	0	0.4	0.9	1	1	1	1	1	1	1	1	1
1998	0	0	0	0	0.6	0.4	0.9	1	1	1	1	1	1	1	1	1
1999	0	0	0	0	0.3	0.9	0.9	1	1	1	1	1	1	1	1	1

Table 7.7.5.1 Continued

	age															
Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2000	0	0	0	0	0.2	0.8	1	1	1	1	1	1	1	1	1	1
2001	0	0	0	0	0.3	0.9	0.9	1	1	1	1	1	1	1	1	1
2002	0	0	0	0	0.1	0.9	1	1	1	1	1	1	1	1	1	1
2003	0	0	0	0	0.2	0.7	1	1	1	1	1	1	1	1	1	1
2004	0	0	0	0	0.3	0.9	1	1	1	1	1	1	1	1	1	1
2005	0	0	0	0	0.3	0.9	1	1	1	1	1	1	1	1	1	1
2006	0	0	0	0	0.3	0.8	1	1	1	1	1	1	1	1	1	1
2007	0	0	0	0	0.1	0.7	0.9	1	1	1	1	1	1	1	1	1
2008	0	0	0	0	0.1	0.6	0.9	1	1	1	1	1	1	1	1	1
2009	0	0	0	0	0.4	0.6	0.9	1	1	1	1	1	1	1	1	1
2010	0	0	0	0	0.4	0.8	0.9	1	1	1	1	1	1	1	1	1
2011	0	0	0	0	0.4	0.8	1	1	1	1	1	1	1	1	1	1
2012	0	0	0	0	0.4	0.8	1	1	1	1	1	1	1	1	1	1
2013	0	0	0	0	0.4	0.8	1	1	1	1	1	1	1	1	1	1

Table 7.7.2.1. Norwegian spring-spawning herring. The stock summary of the exploratory TISVPA run.

year	R(0)	B(0+)	SSB	F(5-14) weighted by abundance
1986	13750	1994	357	0.918
1987	10777	3462	406	0.243
1988	26008	3797	2198	0.042
1989	68425	4531	3572	0.027
1990	127426	5131	4291	0.019
1991	338460	5833	4222	0.021
1992	386658	6932	4295	0.024
1993	117764	8012	4148	0.057
1994	38427	9178	4275	0.120
1995	12243	10060	4296	0.202
1996	53380	10136	4923	0.170
1997	32946	10046	6319	0.164
1998	166360	8685	6978	0.139
1999	172964	9274	7176	0.168
2000	64480	8778	6057	0.195
2001	42941	7275	4922	0.168
2002	320048	7136	4182	0.184
2003	155296	8523	4523	0.150
2004	261602	10120	5460	0.126
2005	70756	10527	5466	0.171
2006	78238	11154	5495	0.181
2007	37519	10392	5808	0.166
2008	23415	10247	6254	0.209
2009	240417	9753	7183	0.203
2010	60071	9022	6748	0.210
2011	73417	8430	5811	0.153
2012			5219	0.150
2013			5501	

Table 7.7.3.3.1. Norwegian spring spawning herring. Stock in numbers (billions).

Age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1988	26.078	4.009	1.630	3.499	0.731	14.101	0.046	0.013	0.012	0.027	0.012	0.008	0.006	0.004	0.003	0.001
1989	71.645	10.593	1.628	0.657	2.953	0.606	11.626	0.030	0.008	0.005	0.010	0.002	0.004	0.002	0.001	0.001
1990	109.326	29.124	4.305	0.646	0.563	2.538	0.516	9.706	0.023	0.006	0.004	0.005	0.001	0.003	0.002	0.002
1991	309.141	44.448	11.841	1.741	0.539	0.482	2.174	0.434	8.144	0.019	0.004	0.001	0.002	0.000	0.002	0.002
1992	368.141	125.687	18.069	4.812	1.490	0.461	0.413	1.857	0.366	6.806	0.014	0.003	0.001	0.001	0.000	0.003
1993	113.296	149.674	51.101	7.346	4.130	1.252	0.392	0.355	1.587	0.309	5.649	0.010	0.002	0.001	0.000	0.002
1994	38.788	46.059	60.853	20.771	6.296	3.456	0.997	0.330	0.302	1.339	0.249	4.482	0.008	0.002	0.001	0.002
1995	19.595	15.770	18.726	24.736	17.848	5.317	2.637	0.705	0.269	0.252	1.118	0.181	3.259	0.004	0.001	0.002
1996	58.595	7.967	6.412	7.613	21.237	15.040	3.999	1.678	0.392	0.217	0.203	0.897	0.078	1.959	0.000	0.002
1997	33.618	23.823	3.239	2.588	6.520	17.617	11.488	2.569	1.067	0.242	0.182	0.167	0.711	0.051	0.910	0.001
1998	253.704	13.668	9.686	1.303	2.106	5.361	13.497	8.038	1.505	0.616	0.152	0.138	0.114	0.528	0.026	0.440
1999	170.765	103.148	5.557	3.885	1.056	1.588	4.272	9.984	5.746	0.941	0.409	0.091	0.095	0.095	0.350	0.309
2000	57.601	69.428	41.937	2.256	3.216	0.876	1.242	3.279	7.104	3.866	0.540	0.254	0.065	0.045	0.075	0.413
2001	34.675	23.419	28.227	17.041	1.864	2.248	0.722	0.966	2.447	4.909	2.358	0.263	0.152	0.041	0.018	0.280
2002	375.973	14.098	9.521	11.475	14.573	1.455	1.539	0.585	0.742	1.831	3.447	1.559	0.158	0.109	0.032	0.203
2003	165.960	152.859	5.732	3.832	9.693	11.946	1.016	1.022	0.476	0.552	1.330	2.352	1.027	0.087	0.082	0.155
2004	289.718	67.475	62.146	2.327	3.228	8.042	9.604	0.711	0.724	0.388	0.406	0.944	1.498	0.681	0.039	0.182
2005	62.009	117.790	27.432	25.239	1.981	2.693	6.523	7.604	0.509	0.495	0.310	0.301	0.655	0.917	0.390	0.044
2006	70.164	25.211	47.890	11.140	21.308	1.617	2.160	5.018	5.682	0.325	0.312	0.231	0.198	0.435	0.469	0.243
2007	24.334	28.526	10.249	19.442	9.518	17.663	1.316	1.700	3.645	4.174	0.197	0.197	0.171	0.117	0.250	0.412
2008	16.972	9.893	11.595	4.161	16.525	7.852	13.528	0.991	1.238	2.461	3.118	0.126	0.146	0.133	0.078	0.411
2009	47.926	6.900	3.997	4.635	3.548	13.713	6.136	9.514	0.668	0.828	1.574	2.341	0.081	0.092	0.092	0.275
2010	7.966	19.485	2.803	1.553	3.811	2.915	10.695	4.433	6.398	0.442	0.469	0.962	1.794	0.028	0.071	0.278
2011	19.336	3.239	7.874	1.100	1.242	3.086	2.333	8.218	3.155	4.188	0.218	0.237	0.512	1.378	0.012	0.247
2012	5.649	7.862	1.236	3.042	0.890	0.972	2.439	1.813	6.372	2.211	3.008	0.104	0.095	0.314	1.144	0.091
2013	1.000	2.297	3.195	0.494	2.422	0.720	0.725	1.837	1.316	4.791	1.611	2.257	0.040	0.040	0.210	1.050

Table 7.7.3.3.2. Norwegian spring spawning herring. Fishing mortality.

Age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1988	0.001	0.001	0.009	0.020	0.038	0.043	0.253	0.360	0.750	0.875	1.475	0.500	0.920	1.221	0.897	0.897
1989	0.000	0.000	0.025	0.005	0.001	0.010	0.031	0.131	0.116	0.160	0.458	0.934	0.201	0.184	0.312	0.312
1990	0.000	0.000	0.006	0.032	0.005	0.005	0.023	0.026	0.062	0.316	0.927	0.682	1.856	0.070	0.556	0.556
1991	0.000	0.000	0.000	0.005	0.006	0.003	0.007	0.022	0.029	0.157	0.141	0.079	0.392	-1.000	0.131	0.131
1992	0.000	0.000	0.000	0.003	0.024	0.012	0.003	0.007	0.017	0.036	0.218	0.278	0.316	-1.000	0.140	0.140
1993	0.000	0.000	0.000	0.004	0.028	0.078	0.024	0.011	0.020	0.067	0.082	0.000	0.000	0.000	0.059	0.059
1994	0.000	0.000	0.000	0.002	0.019	0.121	0.196	0.052	0.030	0.031	0.168	0.169	0.469	0.374	0.226	0.226
1995	0.000	0.000	0.000	0.003	0.021	0.135	0.302	0.436	0.064	0.070	0.070	0.689	0.359	-1.000	0.335	0.335
1996	0.000	0.000	0.007	0.005	0.037	0.119	0.292	0.303	0.334	0.029	0.040	0.083	0.277	0.617	0.294	0.294
1997	0.000	0.000	0.011	0.056	0.046	0.116	0.207	0.385	0.400	0.317	0.126	0.234	0.148	0.516	0.578	0.578
1998	0.000	0.000	0.014	0.060	0.132	0.077	0.152	0.186	0.319	0.258	0.360	0.221	0.033	0.261	0.262	0.262
1999	0.000	0.000	0.001	0.039	0.037	0.096	0.115	0.190	0.246	0.406	0.327	0.189	0.604	0.085	0.317	0.317
2000	0.000	0.000	0.001	0.041	0.208	0.044	0.101	0.143	0.220	0.345	0.568	0.362	0.315	0.792	0.405	0.405
2001	0.000	0.000	0.000	0.007	0.098	0.229	0.060	0.113	0.140	0.204	0.264	0.359	0.184	0.097	0.231	0.231
2002	0.000	0.000	0.010	0.019	0.049	0.210	0.260	0.057	0.146	0.169	0.232	0.267	0.447	0.131	0.269	0.269
2003	0.000	0.000	0.001	0.021	0.037	0.068	0.207	0.195	0.053	0.157	0.194	0.301	0.261	0.648	0.113	0.113
2004	0.000	0.000	0.001	0.011	0.031	0.059	0.084	0.184	0.230	0.077	0.150	0.215	0.341	0.406	1.467	1.467
2005	0.000	0.000	0.001	0.019	0.053	0.071	0.112	0.141	0.299	0.313	0.142	0.266	0.260	0.520	0.431	0.431
2006	0.000	0.000	0.002	0.007	0.038	0.056	0.089	0.170	0.158	0.349	0.310	0.153	0.378	0.403	0.396	0.396
2007	0.000	0.000	0.001	0.013	0.042	0.117	0.134	0.167	0.243	0.142	0.298	0.150	0.102	0.256	0.327	0.327
2008	0.000	0.006	0.017	0.010	0.037	0.097	0.202	0.245	0.252	0.297	0.137	0.292	0.310	0.214	0.428	0.428
2009	0.000	0.001	0.046	0.046	0.046	0.099	0.175	0.247	0.262	0.418	0.343	0.116	0.931	0.116	0.126	0.126
2010	0.000	0.006	0.035	0.073	0.061	0.073	0.114	0.190	0.274	0.557	0.534	0.481	0.114	0.678	0.195	0.195
2011	0.000	0.064	0.051	0.062	0.095	0.085	0.102	0.104	0.205	0.181	0.593	0.763	0.339	0.036	0.902	0.902
2012	0.000	0.001	0.017	0.078	0.063	0.142	0.133	0.170	0.135	0.167	0.137	0.803	0.715	0.250	0.012	0.012

Negative fishing mortality -1 means that the fishing mortality was not defined, see TASACS manual.

Table 7.7.3.3.3 Norwegian spring spawning herring. Final stock summary table.

Run	id:	20130829	110818.2
Process:	Ordinary	assessment	
Model:	VPA		

Year	Recruit	TSB	SSB	Landings	Unweighted	Weighted F with stock numbers
	Age 0 in billions	Million tonnes	Million tonnes	tonnes	F5-14	WF5-14
1988	26.078	3.430	2.006	135301	0.729	0.049
1989	71.645	4.089	3.260	103830	0.254	0.030
1990	109.326	4.623	3.840	86411	0.452	0.022
1991	309.141	5.263	3.748	84683	0.107	0.024
1992	368.141	6.302	3.830	104448	0.114	0.028
1993	113.296	7.374	3.775	232457	0.034	0.065
1994	38.788	8.427	3.905	479228	0.183	0.133
1995	19.595	9.219	3.862	905501	0.273	0.235
1996	58.595	9.304	4.339	1220283	0.239	0.201
1997	33.618	9.192	5.553	1426507	0.303	0.190
1998	253.704	8.049	6.235	1223131	0.213	0.161
1999	170.765	9.164	6.353	1235433	0.258	0.198
2000	57.601	8.517	5.396	1207201	0.329	0.231
2001	34.675	7.129	4.386	766136	0.188	0.196
2002	375.973	7.593	3.847	807795	0.219	0.215
2003	165.960	9.121	4.746	789510	0.220	0.132
2004	289.718	11.042	5.905	794066	0.321	0.118
2005	62.009	11.574	5.966	1003243	0.256	0.159
2006	70.164	12.475	6.204	968958	0.246	0.165
2007	24.334	11.867	6.957	1266993	0.193	0.143
2008	16.972	11.679	7.532	1545656	0.247	0.180
2009	47.926	10.823	8.528	1687373	0.283	0.177
2010	7.966	9.191	7.919	1457014	0.321	0.185
2011	19.336	7.524	6.729	992998	0.331	0.142
2012	5.649	6.539	5.832	825999	0.266	0.144
2013		5.573	5.006			

The GM recruitment over the years 1988-2009 is 79 billion

Table 7.10.1.1 Norwegian Spring-spawning herring. Input to short-term prediction. Stock size is in millions and weight in kg.

2013								
Age	Stock size	Natural mortality	Maturity ogive	Prop. of M bef. spaw.	Prop. of F bef. spaw.	Weight in stock	Exploit. pattern	Weight in catch
0	79000	0.90	0	0	0	0.001	0.000	0.000
1	2297	0.90	0	0	0	0.010	0.015	0.035
2	3195	0.90	0	0	0	0.044	0.033	0.110
3	494	0.15	0	0	0	0.138	0.054	0.196
4	2422	0.15	0.4	0	0	0.204	0.060	0.249
5	720	0.15	0.8	0	0	0.267	0.099	0.278
6	725	0.15	1	0	0	0.305	0.145	0.296
7	1837	0.15	1	0	0	0.309	0.191	0.319
8	1316	0.15	1	0	0	0.320	0.226	0.333
9	4791	0.15	1	0	0	0.328	0.324	0.347
10	1611	0.15	1	0	0	0.346	0.349	0.360
11	2257	0.15	1	0	0	0.350	0.491	0.370
12	40	0.15	1	0	0	0.390	0.482	0.388
13	40	0.15	1	0	0	0.377	0.259	0.385
14	210	0.15	1	0	0	0.389	0.333	0.387
15	1050	0.15	1	0	0	0.393	0.333	0.410

2014 and 2015								
Age	Stock size	Natural mortality	Maturity ogive	Prop. of M bef. spaw.	Prop. of F bef. spaw.	Weight in stock	Exploit. pattern	Weight in catch
0	79000	0.90	0	0	0	0.001	0.000	0.000
1		0.90	0	0	0	0.010	0.015	0.035
2		0.90	0	0	0	0.044	0.033	0.110
3		0.15	0	0	0	0.131	0.054	0.196
4		0.15	0.4	0	0	0.191	0.060	0.249
5		0.15	0.8	0	0	0.244	0.099	0.278
6		0.15	1	0	0	0.275	0.145	0.296
7		0.15	1	0	0	0.292	0.191	0.319
8		0.15	1	0	0	0.312	0.226	0.333
9		0.15	1	0	0	0.327	0.324	0.347
10		0.15	1	0	0	0.342	0.349	0.360
11		0.15	1	0	0	0.353	0.491	0.370
12		0.15	1	0	0	0.381	0.482	0.388
13		0.15	1	0	0	0.372	0.259	0.385
14		0.15	1	0	0	0.389	0.333	0.387
15		0.15	1	0	0	0.393	0.333	0.410

Table 7.10.2.1. Norwegian spring spawning herring. Short term prediction.

Basis:

SSB(2013)=5.006 million t

Landings (2013)=692 (sum of national quota)

Fw(2013)=0.150

SSB(2014)=4.123 million t

The fishing mortality applies according to the agreed management plan (F(management plan)) is 0.099

Rationale	Landings	Fmult	Basis	F(2014)	SSB(2015)
Zero catch	0	0.00	F=0	0.000	3.914
Status quo	588	1.00	F(2012)	0.144	3.390
Agreed management plan	44	0.07	F(management plan)*0.1	0.010	3.875
	112	0.17	F(management plan)*0.25	0.025	3.814
	211	0.34	F(management plan)*0.5	0.049	3.725
	315	0.51	F(management plan)*0.75	0.074	3.633
	376	0.62	F(management plan)*0.9	0.089	3.578
	419	0.69	F(management plan)	0.099	3.541
	454	0.76	F(management plan)*1.1	0.109	3.509
	513	0.85	F(management plan)*1.25	0.123	3.456
	519	0.87	F(management plan)*1.26	0.125	3.451
	610	1.04		0.150	3.370

Landings weights in thousand tonnes, stock biomass weight in million tonnes.

F_w=Fishing mortality weighted by population numbers (age groups 5-14).

Table 7.10.2. 2 Norwegian spring-spawning herring. Detailed short term prediction

2013

Age	Stockno.	Stockno.	Biomass	Biomass	SSB	SSB	F	Catches in	Catches in
	1-Jan.	spawning time	01-Jan	spawning time	01-Jan	spawning time		numbers	weight
0	79000	79000	79	79	0	0	0.000	0	0
1	2297	2297	23	23	0	0	0.008	11	0
2	3195	3195	141	141	0	0	0.016	34	4
3	494	494	68	68	0	0	0.026	12	2
4	2422	2422	494	494	198	198	0.030	66	16
5	720	720	192	192	154	154	0.049	32	9
6	725	725	221	221	221	221	0.071	46	14
7	1837	1837	568	568	568	568	0.094	153	49
8	1316	1316	421	421	421	421	0.111	128	43
9	4791	4791	1571	1571	1571	1571	0.159	654	227
10	1611	1611	557	557	557	557	0.171	236	85
11	2257	2257	790	790	790	790	0.241	450	167
12	40	40	16	16	16	16	0.236	8	3
13	40	40	15	15	15	15	0.127	4	2
14	210	210	82	82	82	82	0.163	29	11
15	1050	1050	413	413	413	413	0.163	147	60
	102005	102005	5651	5651	5006	5006	0.150	2009	692
	millions	millions	kt	kt	kt	kt	Wt. F5-14	millions	kt

2014

Age	Stockno.	Stockno.	Biomass	Biomass	SSB	SSB	F	Catches in	Catches in
	1-Jan.	spawningtime	01-Jan	spawningtime	01-Jan	spawningtime		numbers	weight
0	79000	79000	79	79	0	0	0.000	0	0
1	32119	32119	321	321	0	0	0.005	108	4
2	927	927	41	41	0	0	0.011	7	1
3	1278	1278	168	168	0	0	0.018	21	4
4	414	414	79	79	32	32	0.020	8	2
5	2024	2024	494	494	395	395	0.033	61	17
6	590	590	162	162	162	162	0.048	26	8
7	581	581	170	170	170	170	0.063	33	11
8	1440	1440	449	449	449	449	0.075	96	32
9	1014	1014	331	331	331	331	0.107	96	33
10	3519	3519	1205	1205	1205	1205	0.115	356	128
11	1169	1169	413	413	413	413	0.162	163	60
12	1527	1527	582	582	582	582	0.159	209	81
13	27	27	10	10	10	10	0.085	2	1
14	30	30	12	12	12	12	0.110	3	1
15	922	922	362	362	362	362	0.110	89	37
	126581	126581	4878	4878	4123	4123	0.100	1275	418
	millions	millions	kt	kt	kt	kt	Wt. F5-14	millions	kt

Table 7.10.2. 2 (Continued).

2015									
Age	Stockno.	Stockno.	Biomass	Biomass	SSB	SSB	F	Catches in	Catches in
	1-Jan.	spawningtime	01-Jan	spawningtime	01-Jan	spawningtime		numbers	weight
0	79000	79000	79	79	0	0	0.000	0	0
1	32119	32119	321	321	0	0	0.004	82	3
2	12992	12992	572	572	0	0	0.008	71	8
3	373	373	49	49	0	0	0.013	5	1
4	1081	1081	207	207	83	83	0.015	15	4
5	349	349	85	85	68	68	0.025	8	2
6	1686	1686	463	463	463	463	0.036	56	17
7	484	484	141	141	141	141	0.048	21	7
8	470	470	146	146	146	146	0.056	24	8
9	1150	1150	376	376	376	376	0.081	83	29
10	785	785	269	269	269	269	0.087	61	22
11	2699	2699	954	954	954	954	0.123	290	107
12	856	856	326	326	326	326	0.120	90	35
13	1121	1121	418	418	418	418	0.065	65	25
14	21	21	8	8	8	8	0.083	2	1
15	734	734	289	289	289	289	0.083	54	22
	135921	135921	4702	4702	3541	3541	0.082	926	290
	millions	millions	kt	kt	kt	kt	Wt. F5-14	millions	kt

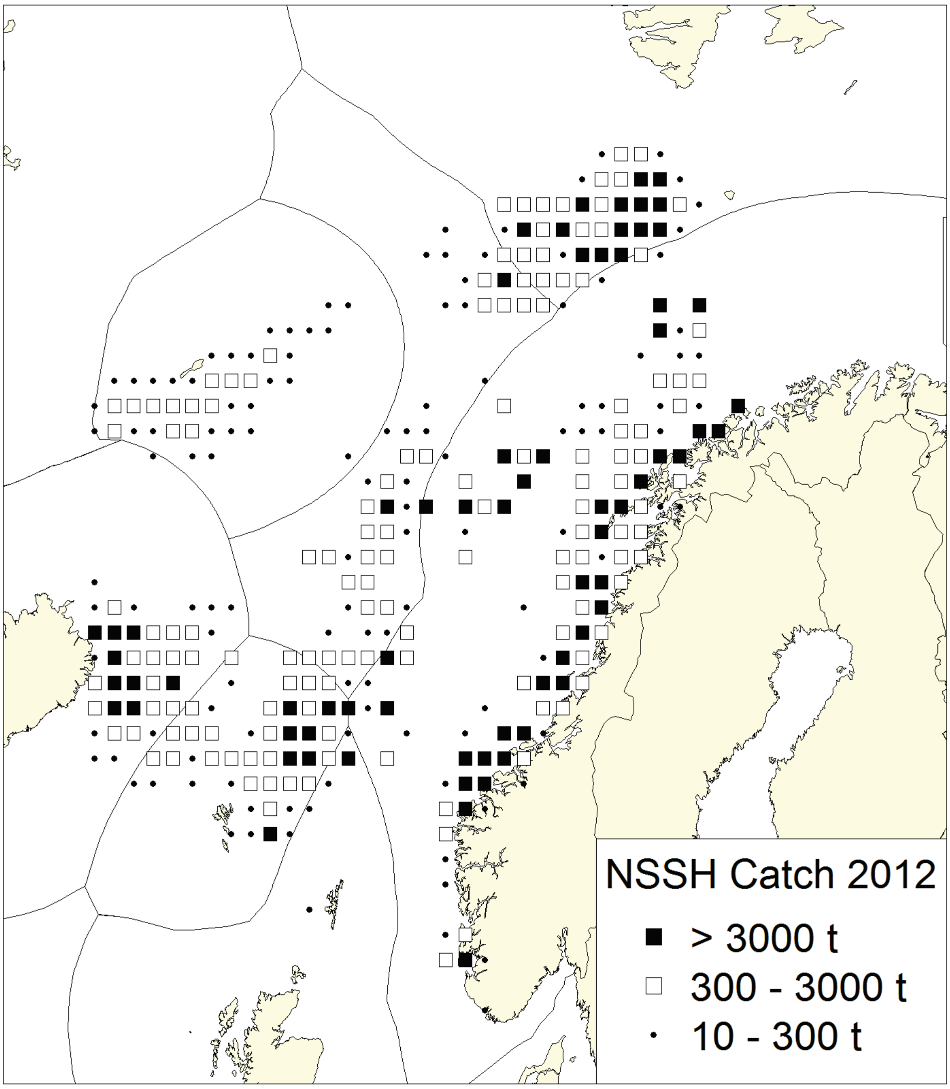

Figure 7.3.1.1. Total reported catches of Norwegian spring-spawning herring in 2012 by ICES rectangle. Grading of the symbols: black dots less than 300 t, open squares 300–3000 t, and black squares > 3000 t.

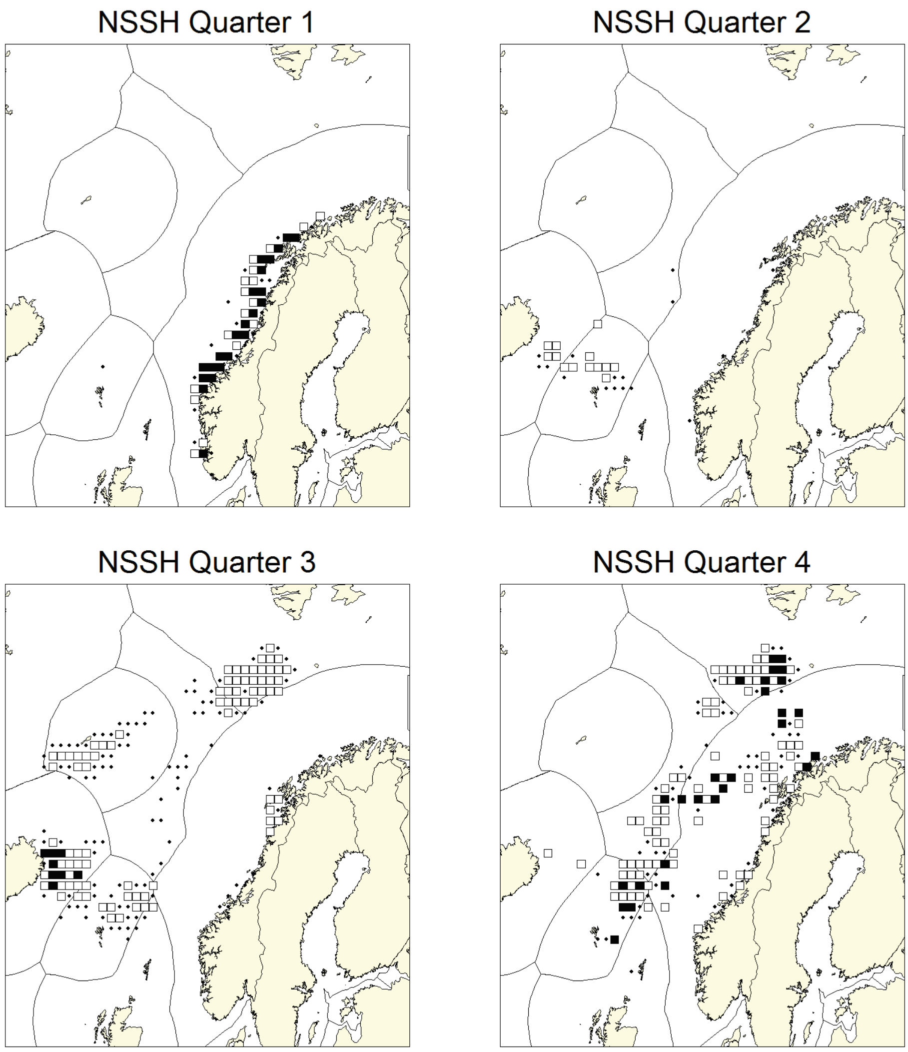

Figure 7.3.1.2. Total reported catches of Norwegian spring-spawning herring in 2012 by quarter and ICES rectangle. Grading of the symbols: black dots less than 300 t, open squares 300–3000 t, and black squares > 3000 t.

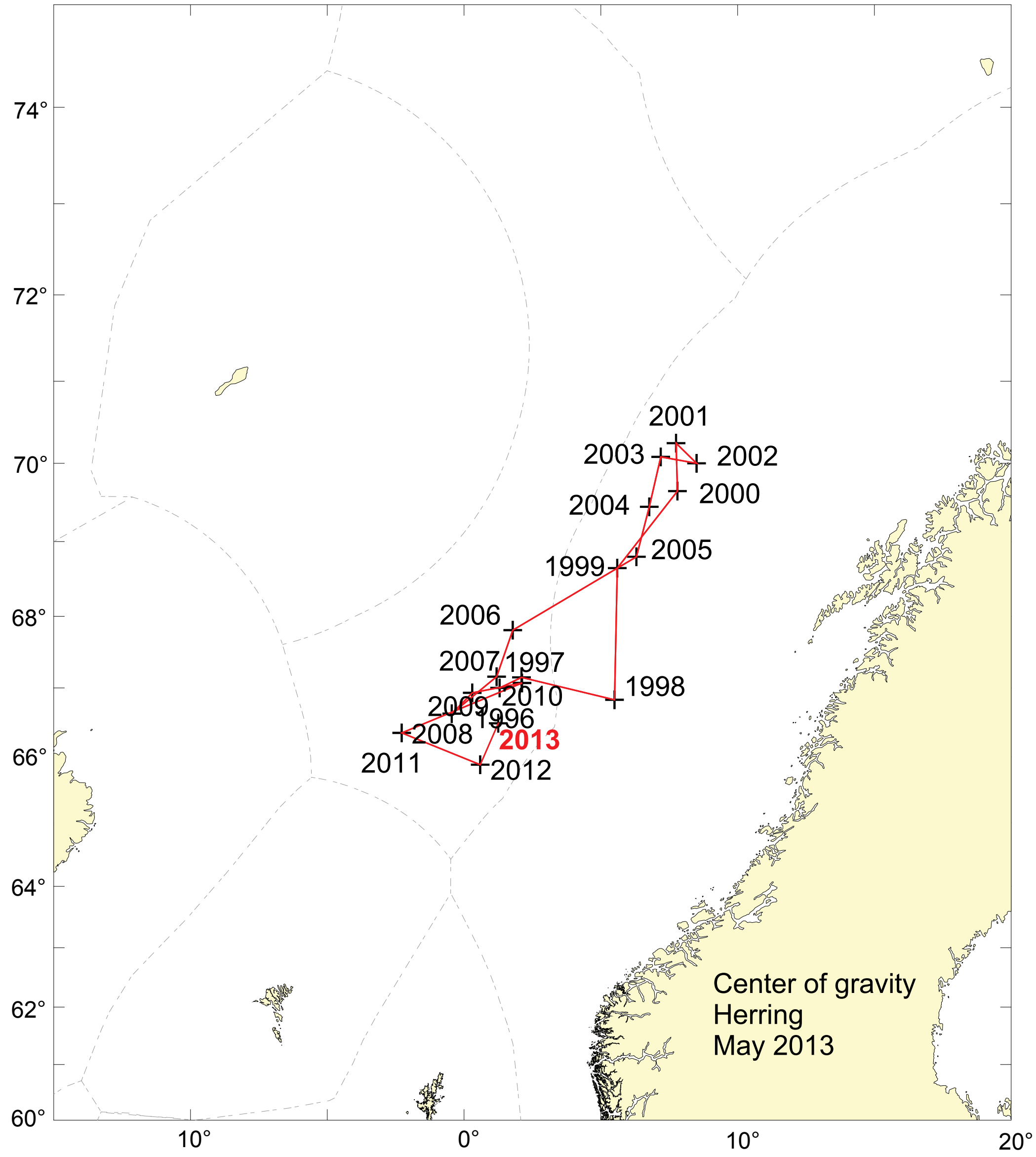

Figure 7.4.2.1 Norwegian spring spawning herring: Centre of gravity of herring during the period 1996-2012 derived from acoustic. Acoustic data from area II and III only, i.e. west of 20°E.

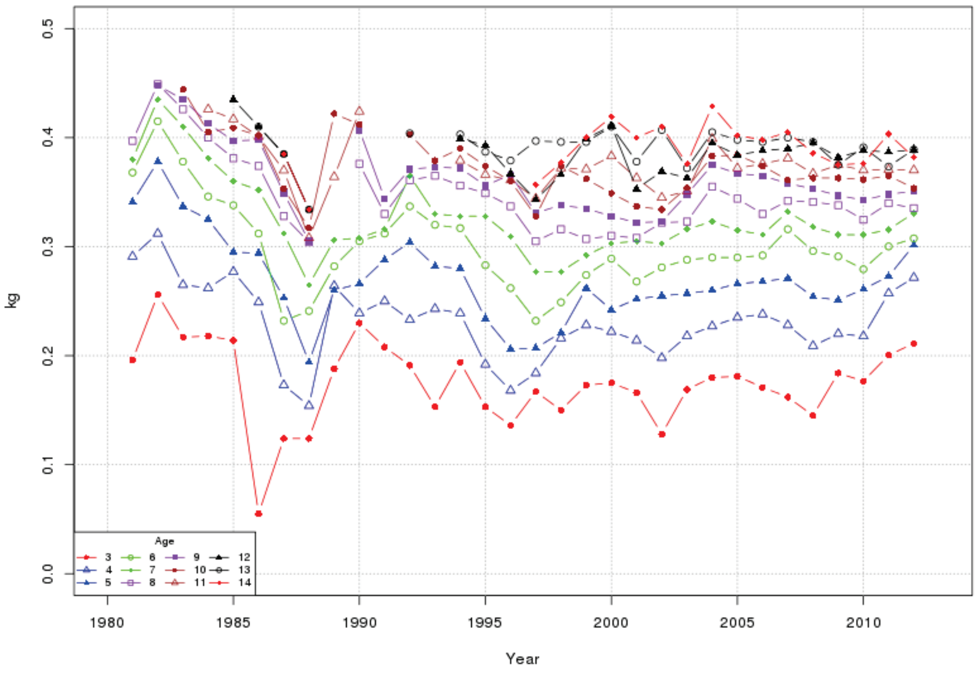

Figure 7.5.4.1. Norwegian spring spawning herring. Mean weight at age by age groups 3-14 in the years 1980-2012 in the catch (weight at age for zero catch numbers were omitted).

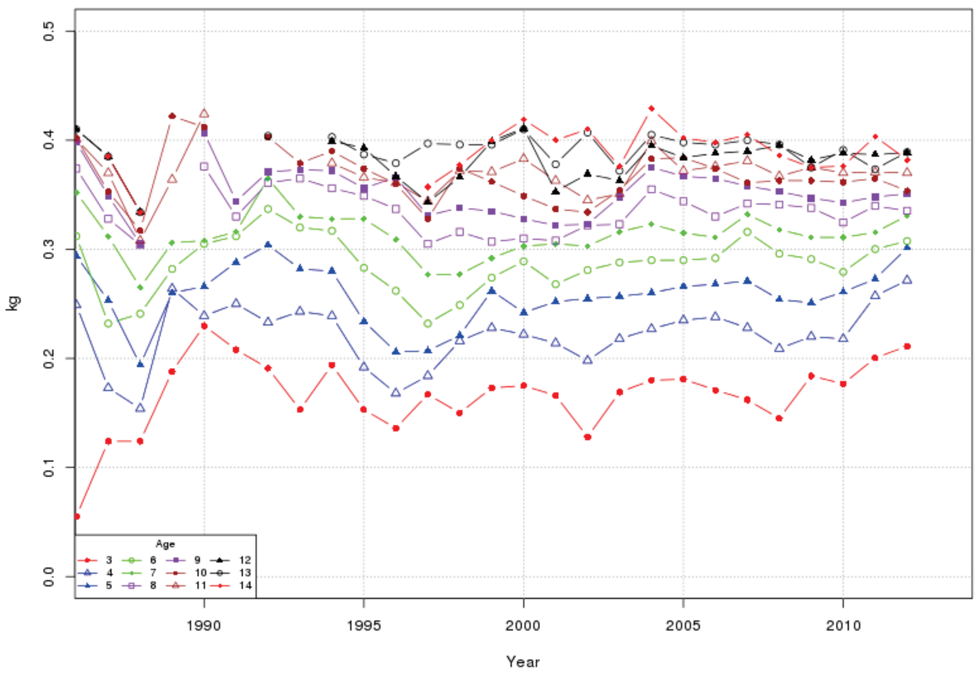

Figure 7.5.4.2. Norwegian spring-spawning herring. Mean weight at age in the stock 1981-2013.

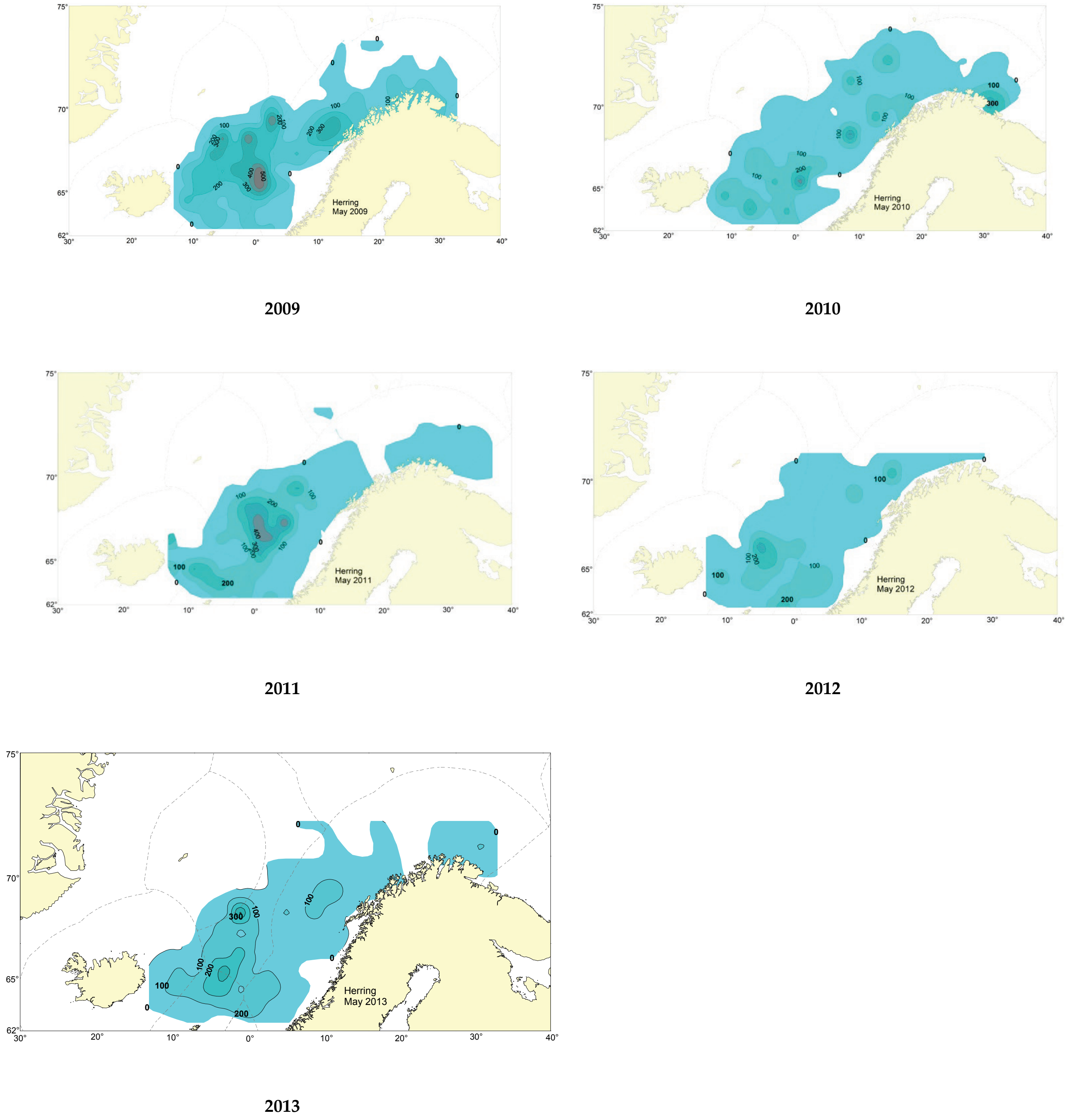

Figure 7.5.7.4.1. Norwegian Spring-Spawning herring. Schematic map of herring acoustic density (sA, m^2/nm^2) found during the survey in May 2009 to 2013.

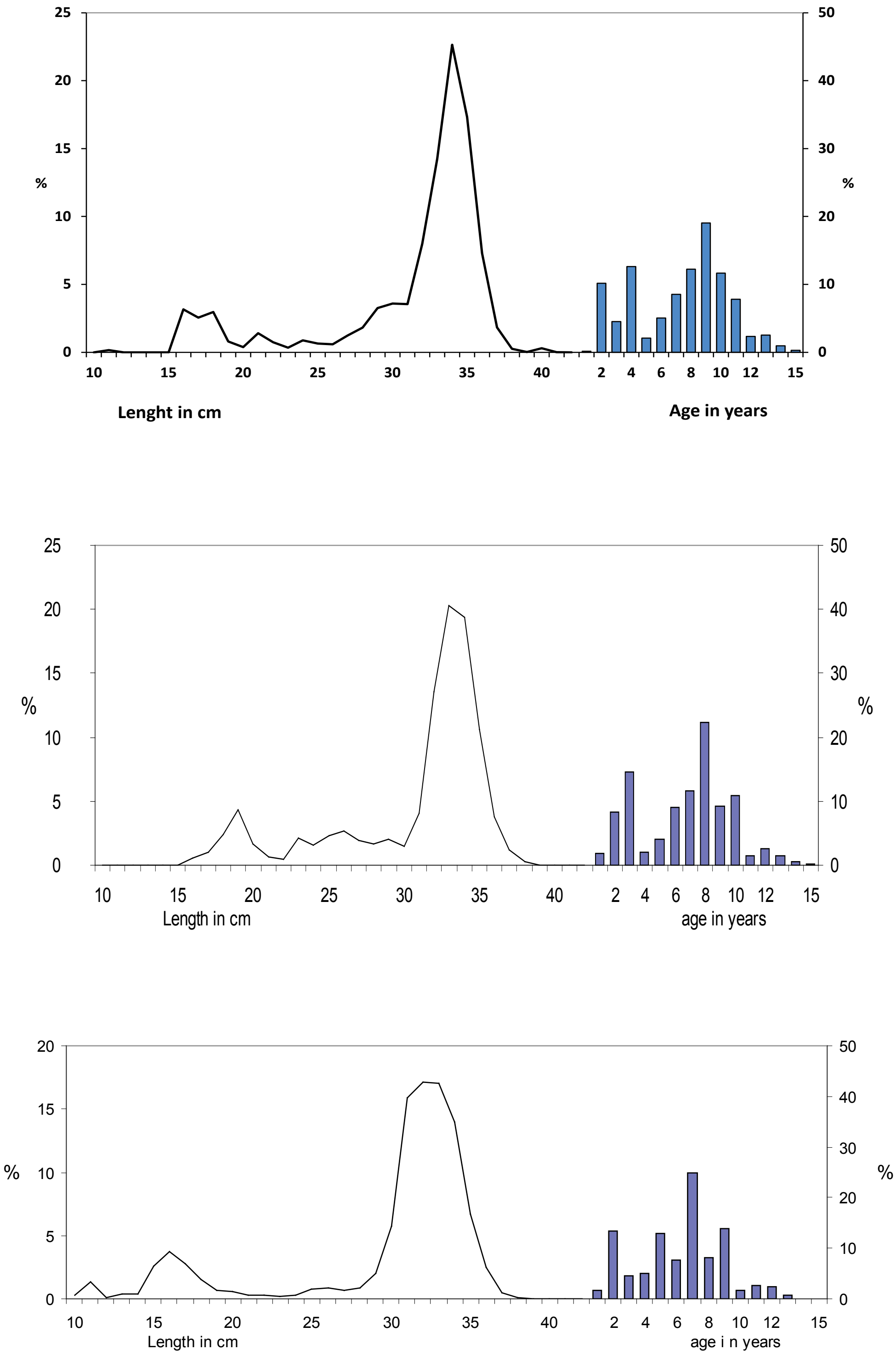

Figure 7.5.7.4.2. Length and age distribution of Norwegian spring spawning herring in the area in the Norwegian Sea and Barents Sea in May 2013 (upper most panel), in 2012 (mid panel) and in 2011 (lowest panel).

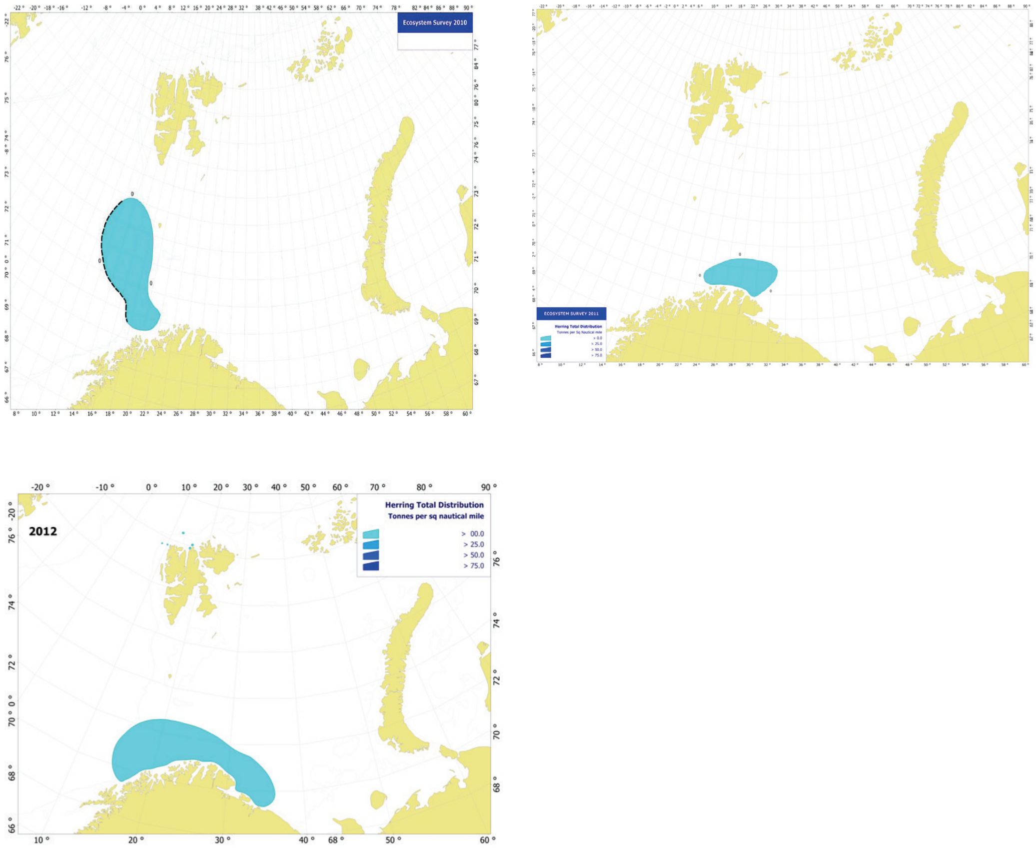

Figure 7.5.7.5.1. Norwegian Spring-Spawning herring. Estimated total density of herring (tonnes/nautical mile^2) in August-September 2010 (upper left panel), 2011 (upper right panel) and 2012 (lower left panel) in Barents Sea. ***Survey 6.***

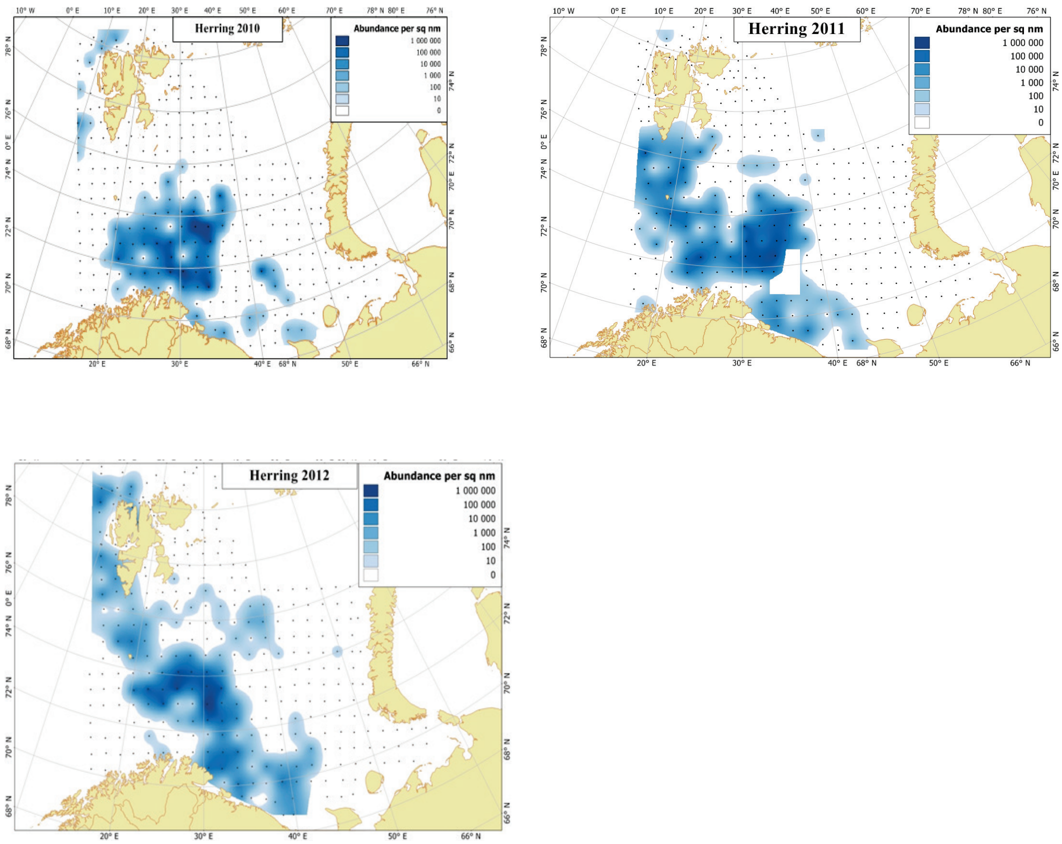

Figure 7.5.7.5.2. Norwegian Spring-Spawning herring. O–group surveys in August/September in the Barents Sea in 2010 to 2012. ***Survey 7.***

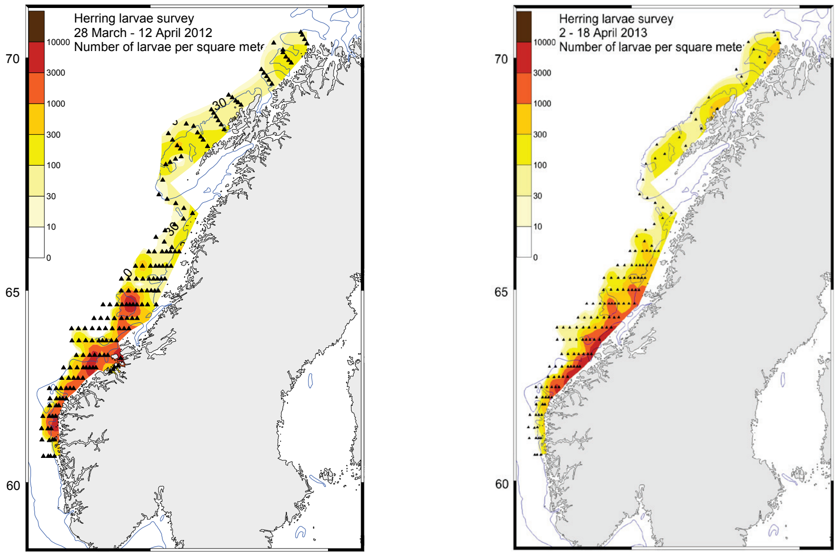

Figure 7.5.7.6.1. Norwegian Spring-Spawning herring. Distribution of herring larvae on the Norwegian shelf in 2012 (left panel) and 2013 (right panel). The 200 m depth line is also shown. *Survey 8.*

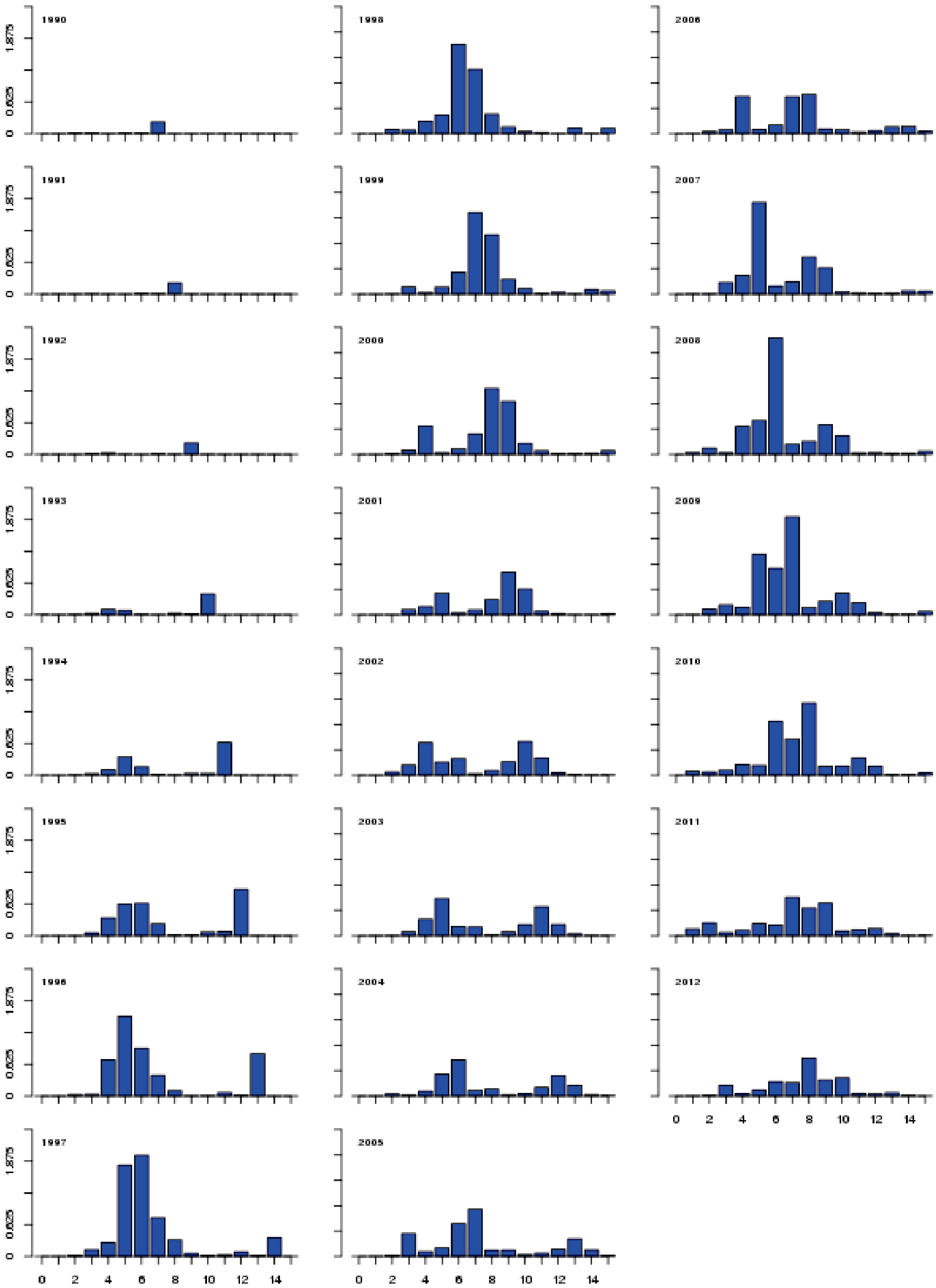

Figure 7.7.1.1. Norwegian spring spawning herring. Age disaggregated catch in numbers plotted. Age is on x-axis. The labels indicate years.

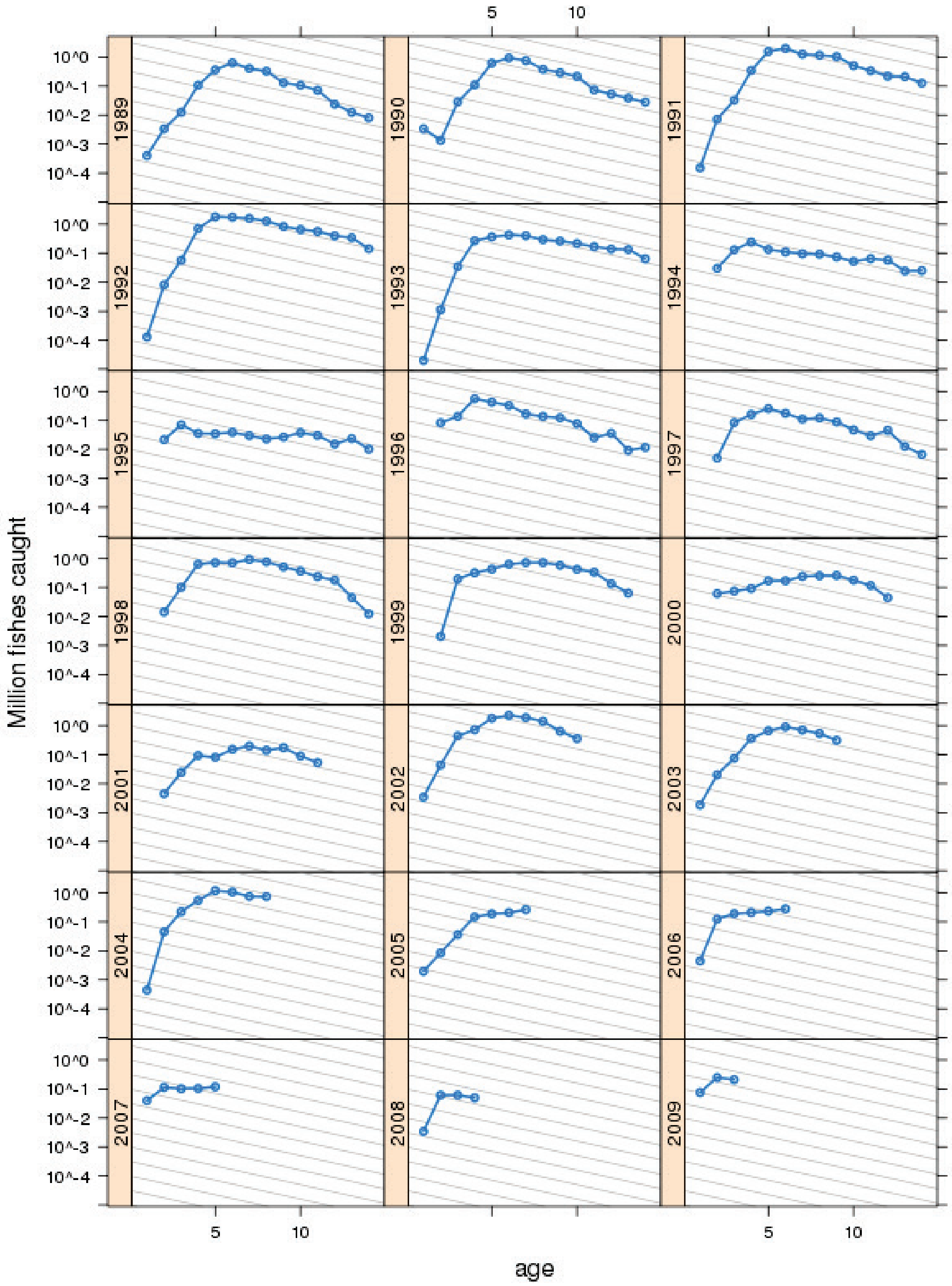

Figure 7.7.1.2. Norwegian spring spawning herring. Age disaggregated catch in numbers plotted on a log scale. Age is on x-axis. The labels indicate year classes and grey lines correspond to Z=0.3.

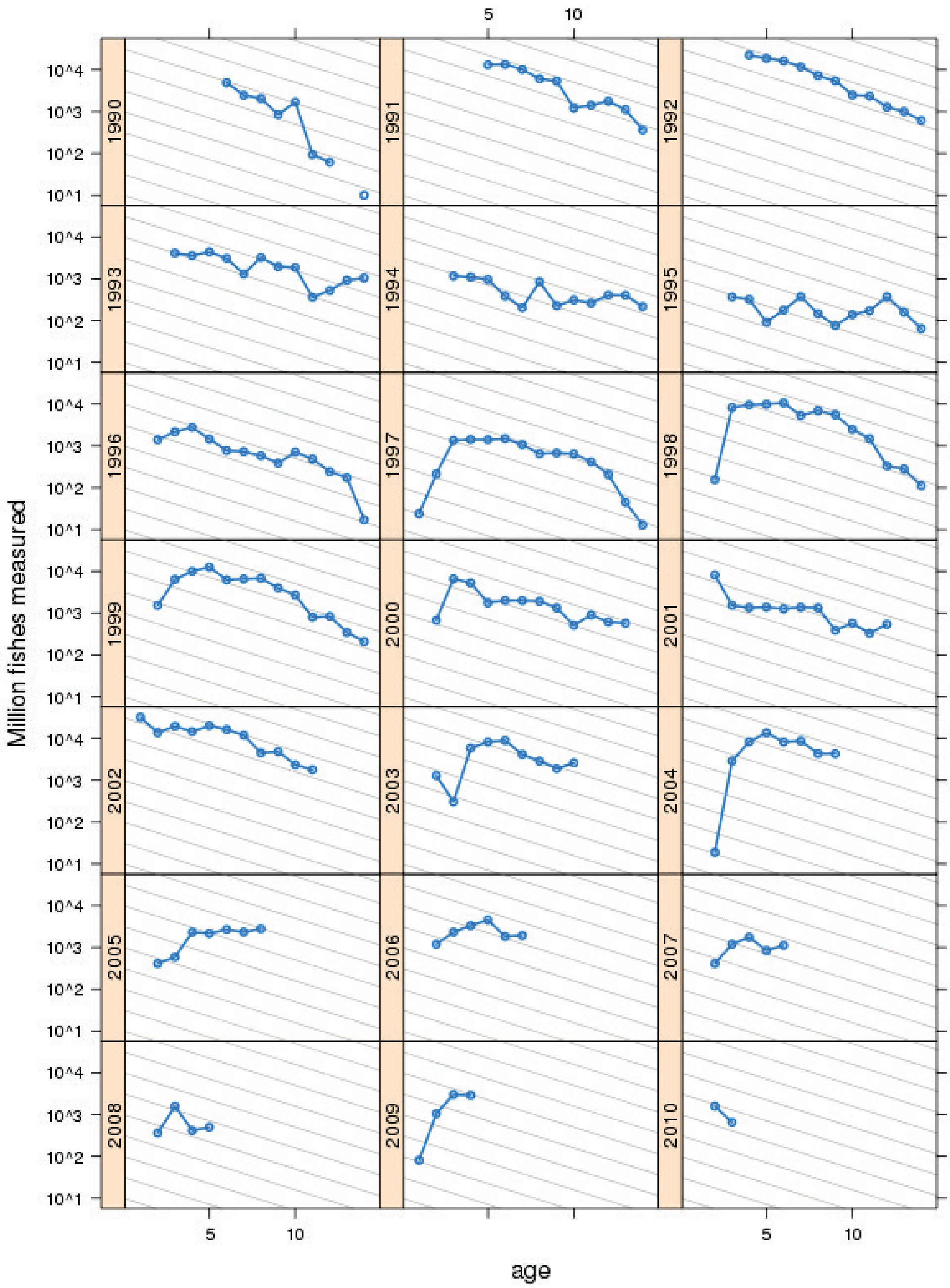

Figure 7.7.1.3. Norwegian spring spawning herring. Age disaggregated abundance indices (billions) from the acoustic survey on the feeding area in the Norwegian Sea in May (survey 5) plotted on a log scale. The labels indicate year classes and grey lines correspond to Z=0.3.

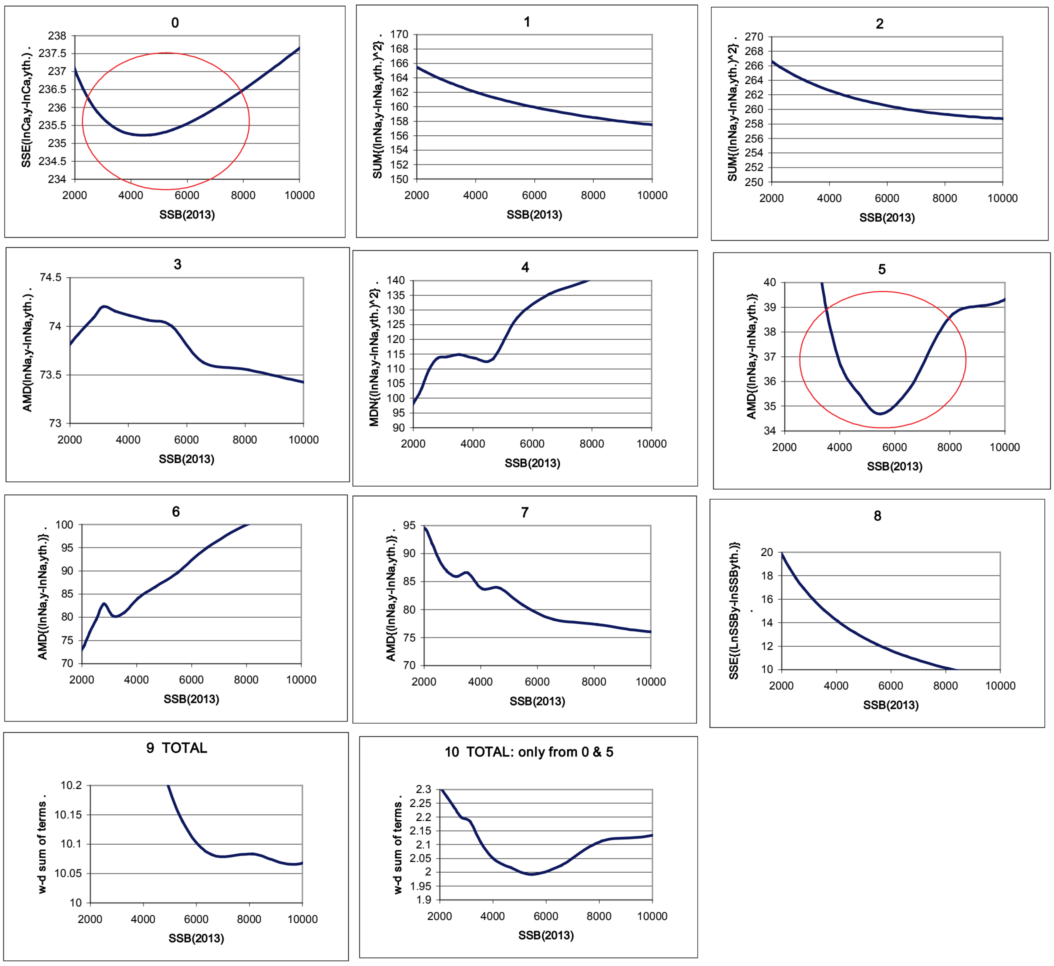

Figure 7.7.2.1. Norwegian spring spawning herring. Profiles of components of the TISVPA objective function : 0 - signal from catch-at-age alone; 1-8 - signals from "surveys" from 1 to 8 respectively (see explanation for numbering of the " surveys" in the text).

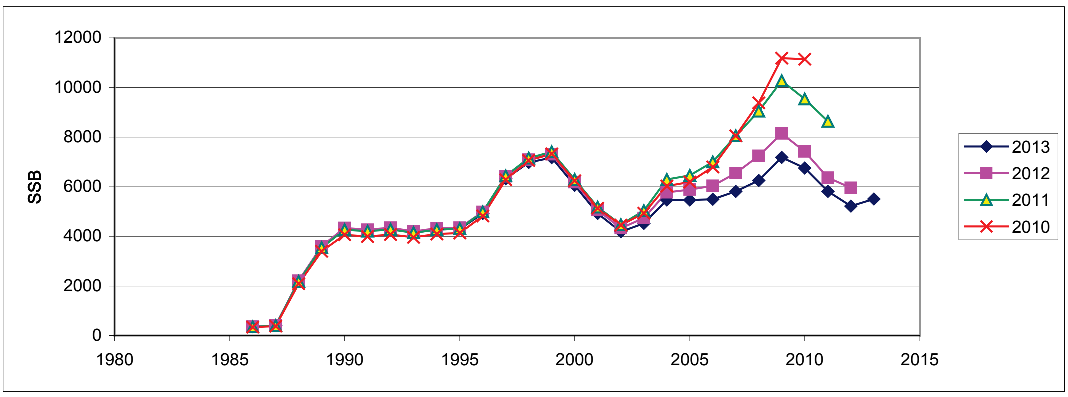

Figure 7.7.2.2. Norwegian spring spawning herring. Results of the TISVPA retrospective runs obtained when inputs only from catch-at-age and survey 5 were used.

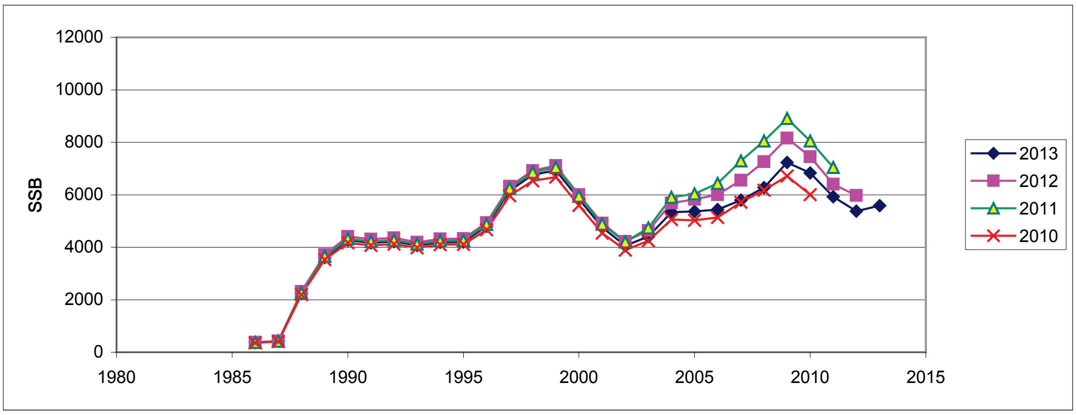

Figure 7.7.2.3. Norwegian spring spawning herring. Results of the TISVPA retrospective runs obtained when input from only catch-at-age was used.

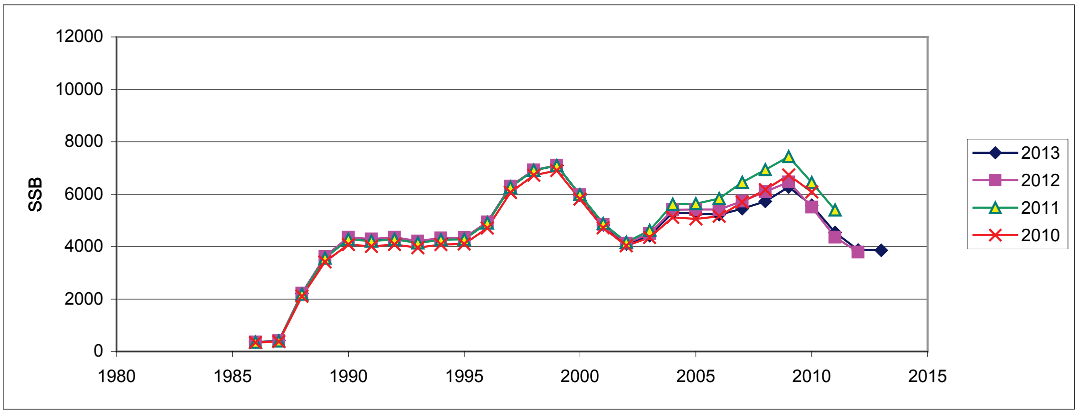

Figure 7.7.2.4. Norwegian spring spawning herring. Results of the TISVPA retrospective runs obtained when input only from age proportions in the data of survey 5 was used.

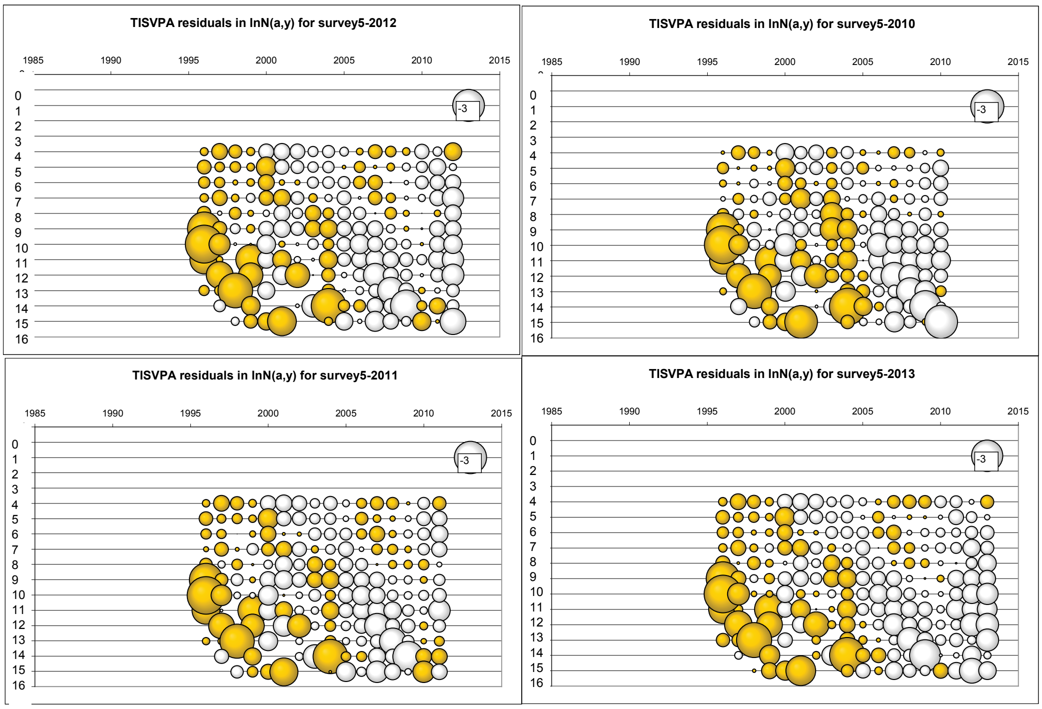

Figure 7.7.2.5. Norwegian spring spawning herring. Residuals of the TISVPA retrospective runs obtained when the model was tuned only at age proportions of survey 5.

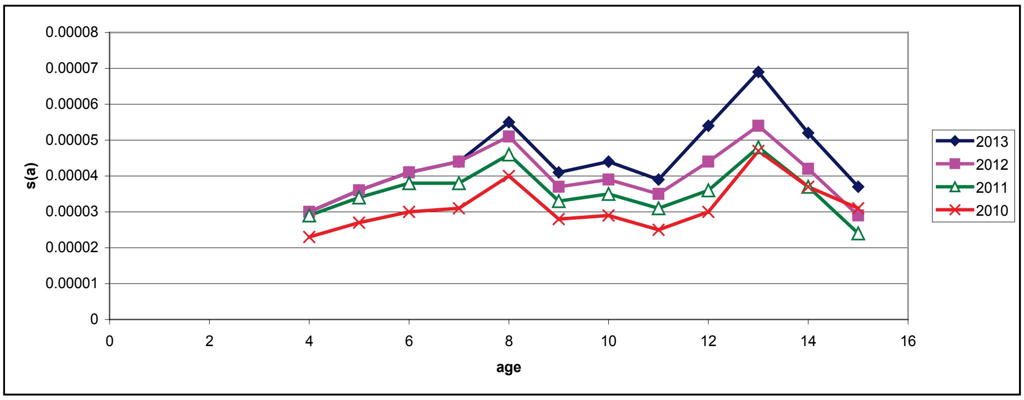

Figure 7.7.2.6. Norwegian spring spawning herring. The TISVPA-derived estimates of average catchability by ages for survey 5 obtained in retrospective runs.

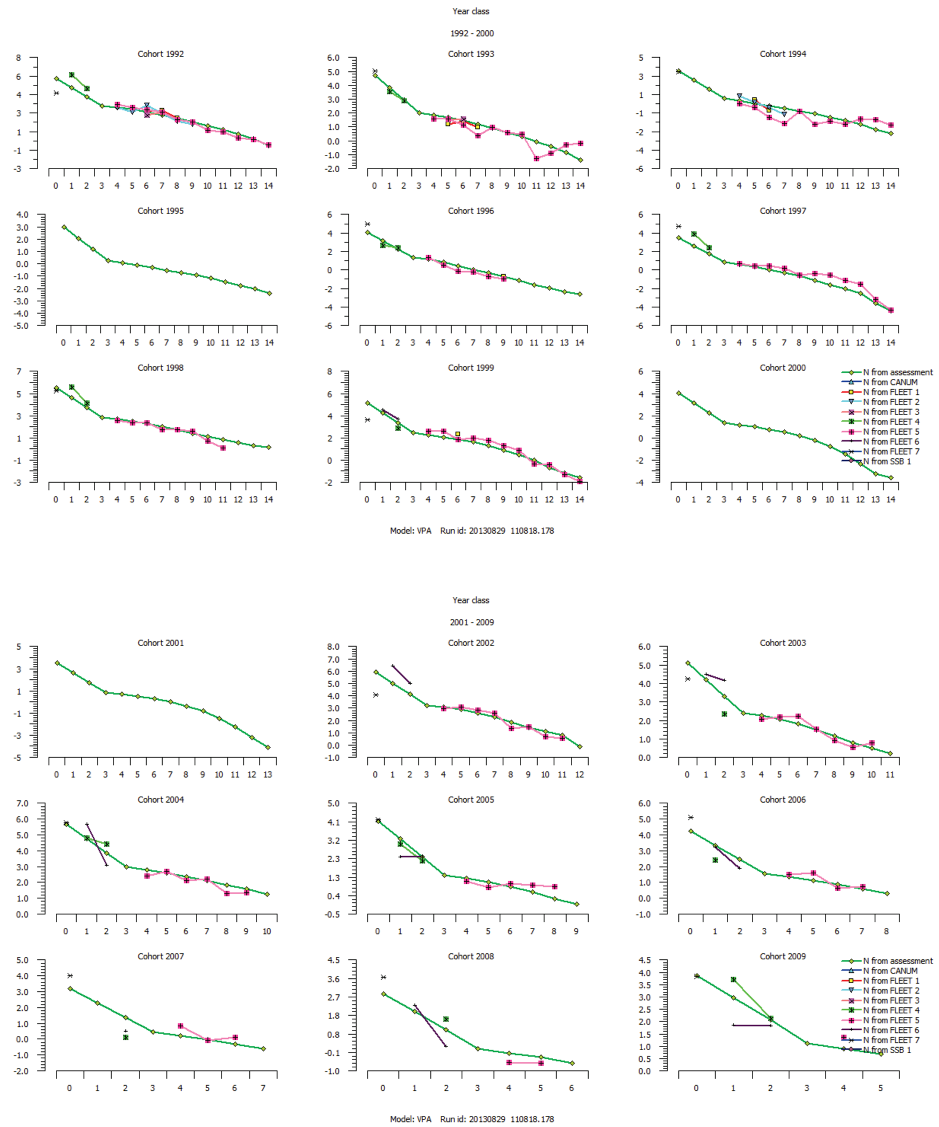

Figure 7.7.3.1 Norwegian spring spawning herring. Year class Ns, excluding values with zero weight.

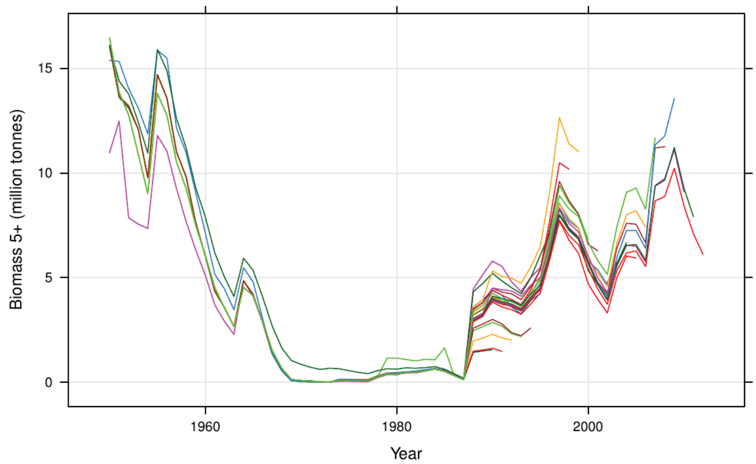

Figure 7.7.3.2.1. Norwegian spring spawning herring. Time series of biomass from different assessment years, from 1988 to 2012 (WKBWNSSH 2013).

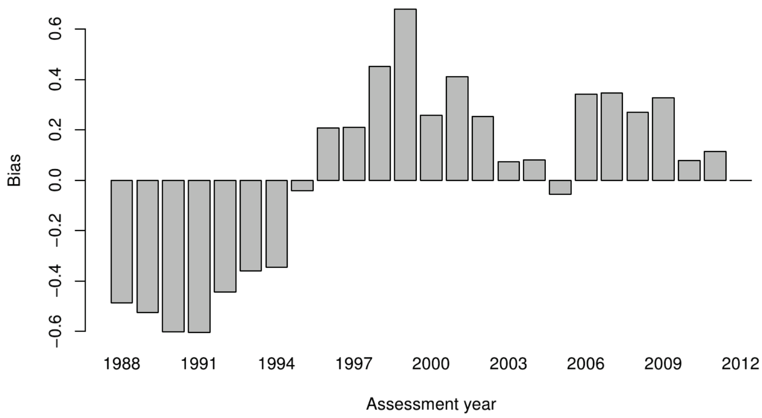

Figure 7.7.3.2.2. Norwegian spring spawning herring. Relative bias in the assessment, each assessment year compared with the assessment from 2012 (WKBWNSSH 2013).

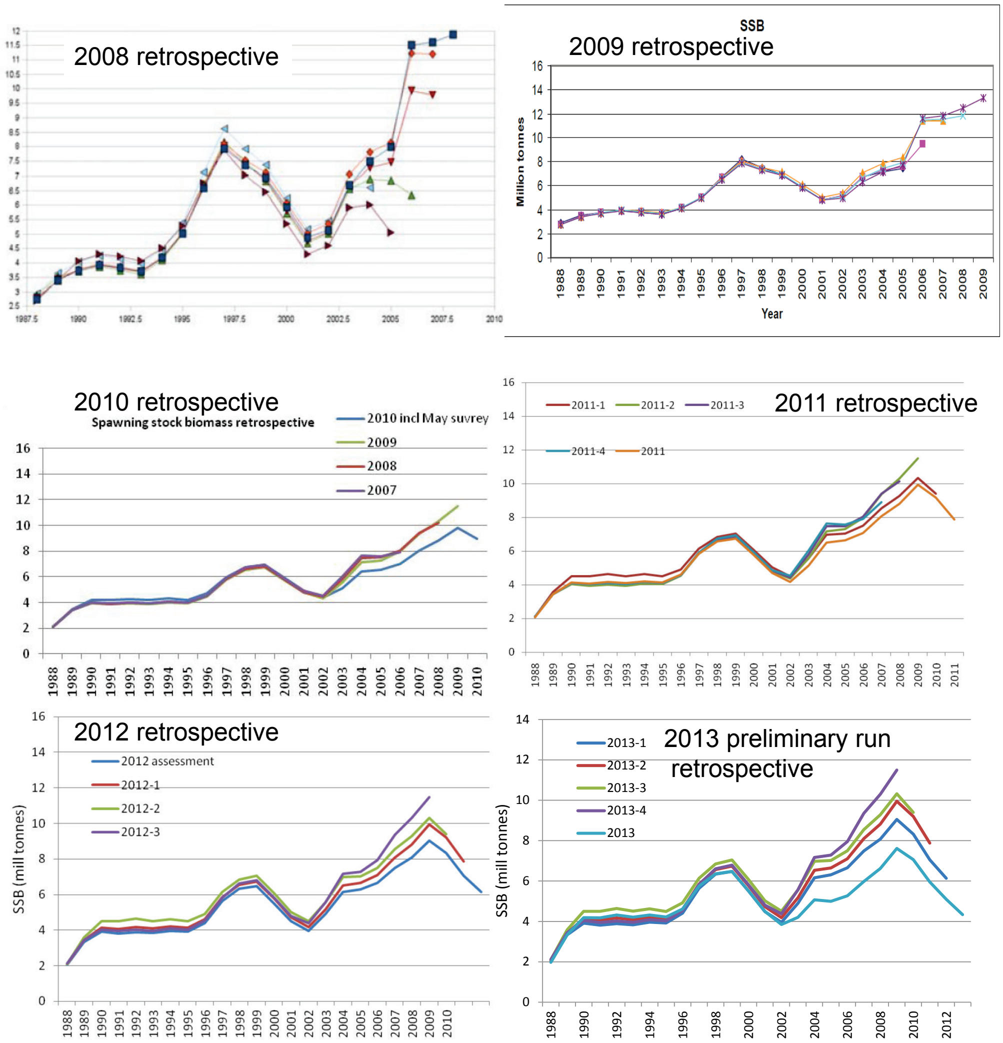

Figure 7.7.3.2.3.Norwegian spring spawning herring. Retrospective plots from assessment years 2008-2013 (2013 preliminary run, see Figure 7.7.5.1 for final run retrospective plot).

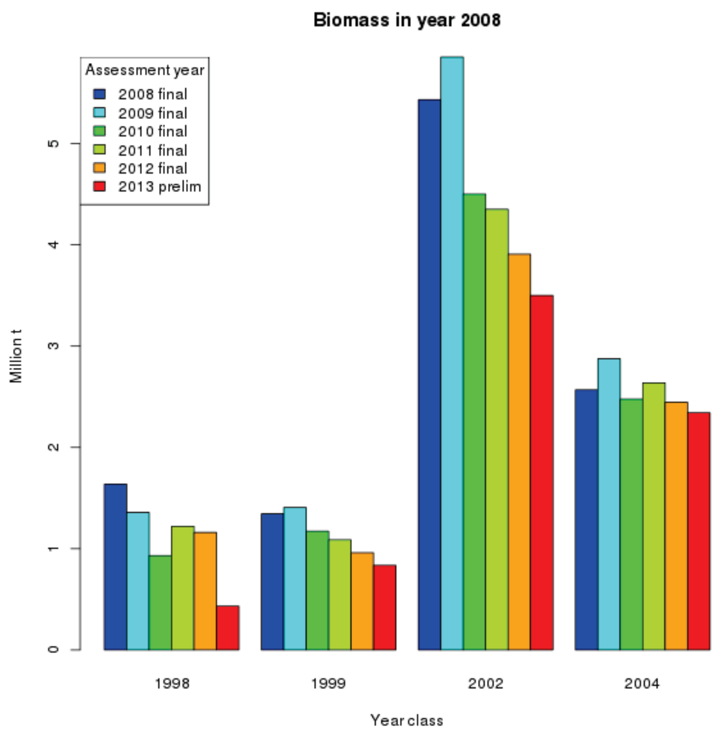

Figure 7.7.3.2.4.Norwegian spring spawning herring. Biomass of year classes of 1998, 1999, 2002, and 2004 as estimated in the assessment year 2008 – 2013 (preliminary assessment).

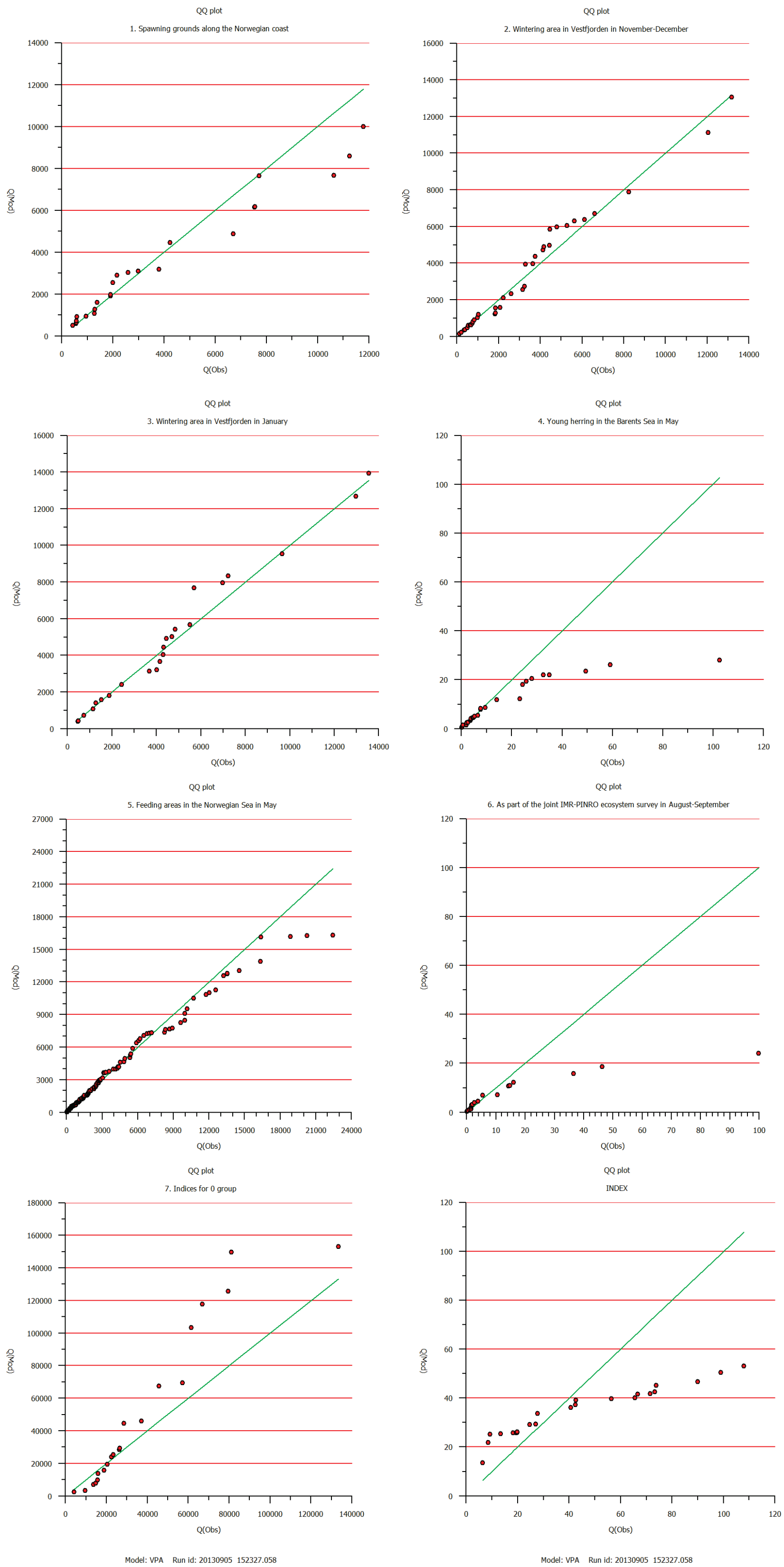

Figure 7.7.3.2.5. Norwegian spring spawning herring. Q-Q plot from the eight different surveys used in tuning in TASACS. First row starts with survey 1 and the last one in row four is larval survey.

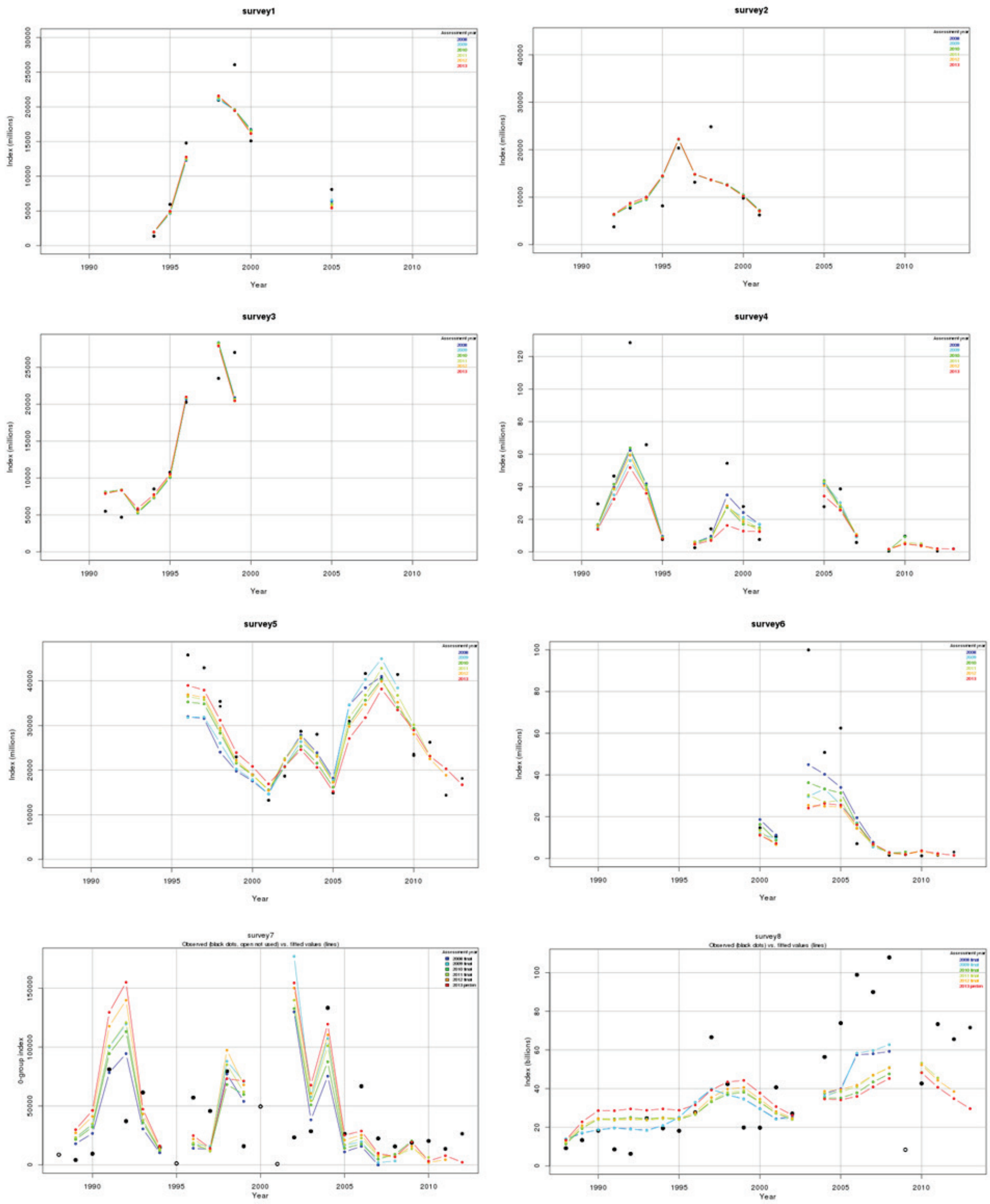

Figure 7.7.3.2.6. Norwegian spring spawning herring. Fit of the survey data in different assessment years. Note tha tsurveys 1-6 are fitted to yearly data, whereas 7 and 8 are fitted to year classes.

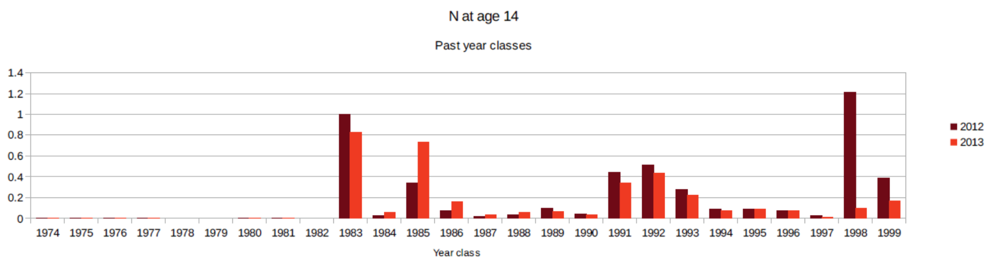

Figure 7.7.3.2.7. Norwegian spring spawning herring. Change in the estimates of numbers at age 14 from 2012 to 2013 assessment, for year classes that have past the oldest true age of 14 years (WD Skagen 2013 WGWIDE).

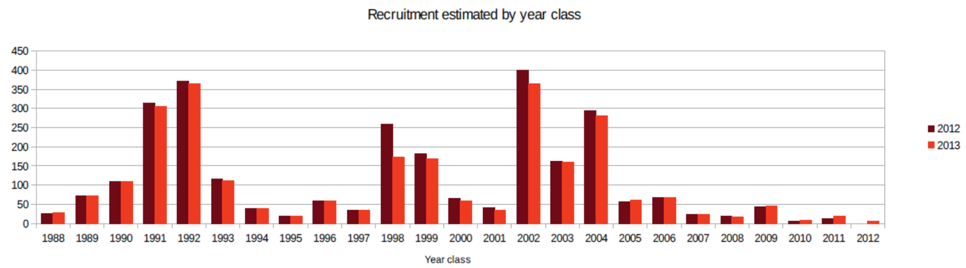

Figure 7.7.3.2.8. Norwegian spring spawning herring Change in the estimates of year class strength (N-values back calculated to age 1) from 2012 to 2013assessment, for all year classes(WD Skagen 2013 WGWIDE).

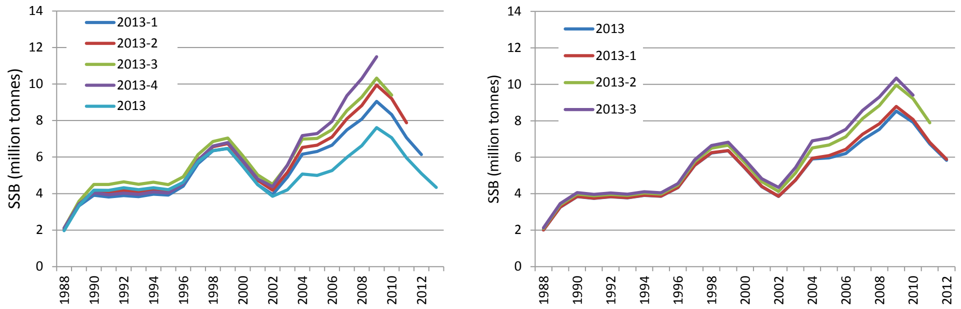

Figure 7.7.3.2.9. Norwegian spring spawning herring. Comparison of the preliminary and final assessment retrospective plots.

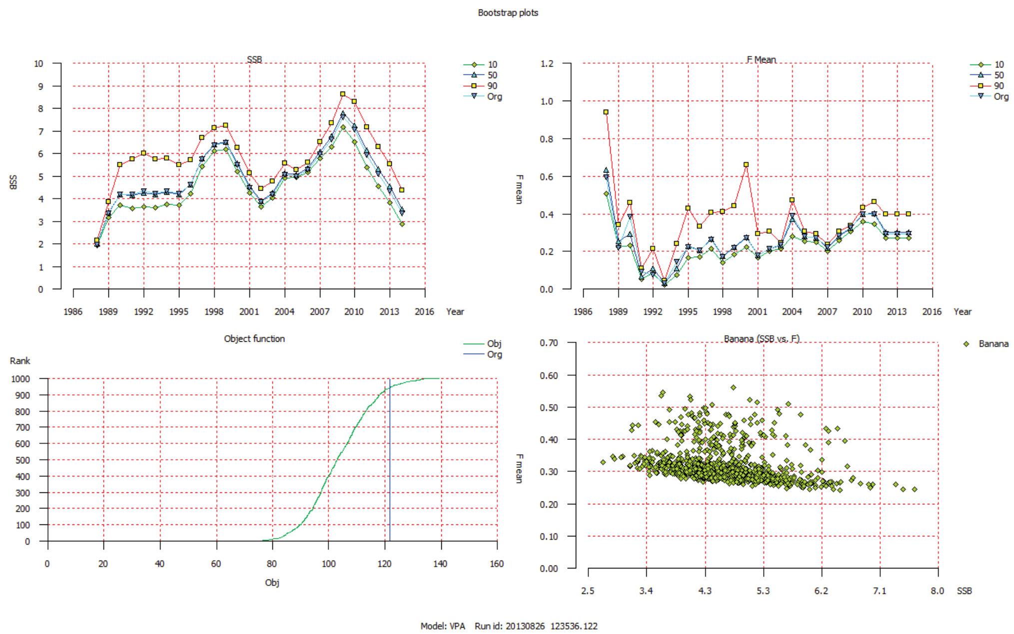

Figure 7.7.3.2.10. Norwegian spring spawning herring. The bootstrap diagnostics from the preliminary run including the 10, 50, and 90 percentiles of the SSB and unweighted F values, the object function and the 'banana plot'.

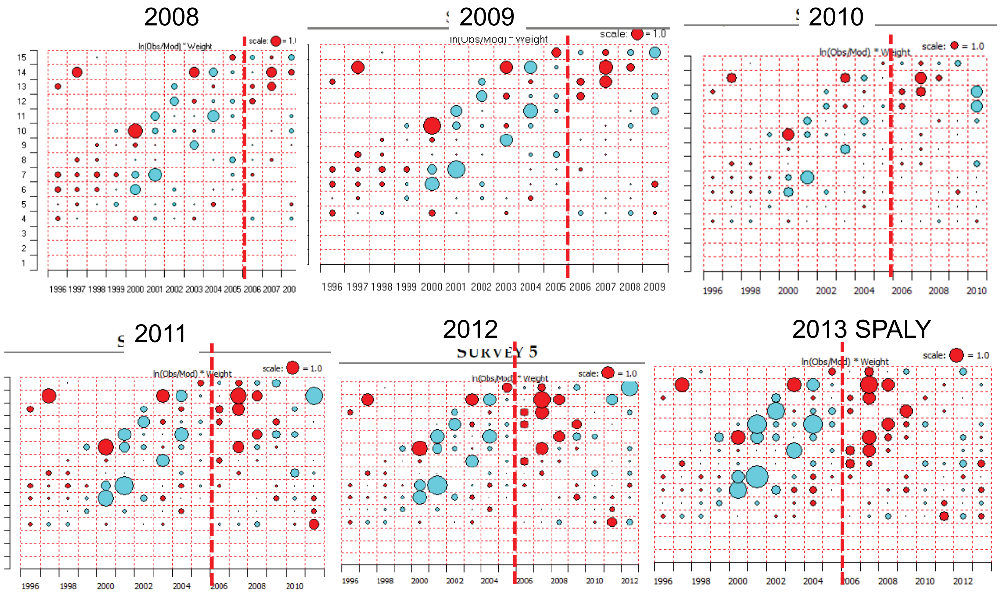

Figure 7.7.3.2.11. Norwegian spring spawning herring. Residual plots from the assesments in 2008 – 2013 (preliminary assessment, residual plot from 2013 final assessment in shown in Figure 7.7.3.3).

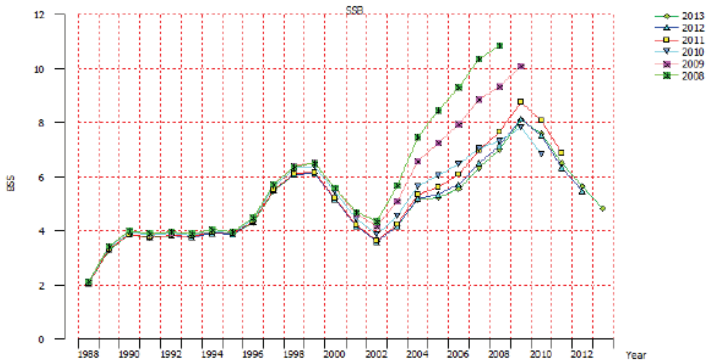

Figure 7.7.3.2.12. Norwegian spring spawning herring. A retrospective plot from an exploratory run with separate survey 5 catchability for the time period 2006-2009 and new algorithm for terminal F-values.

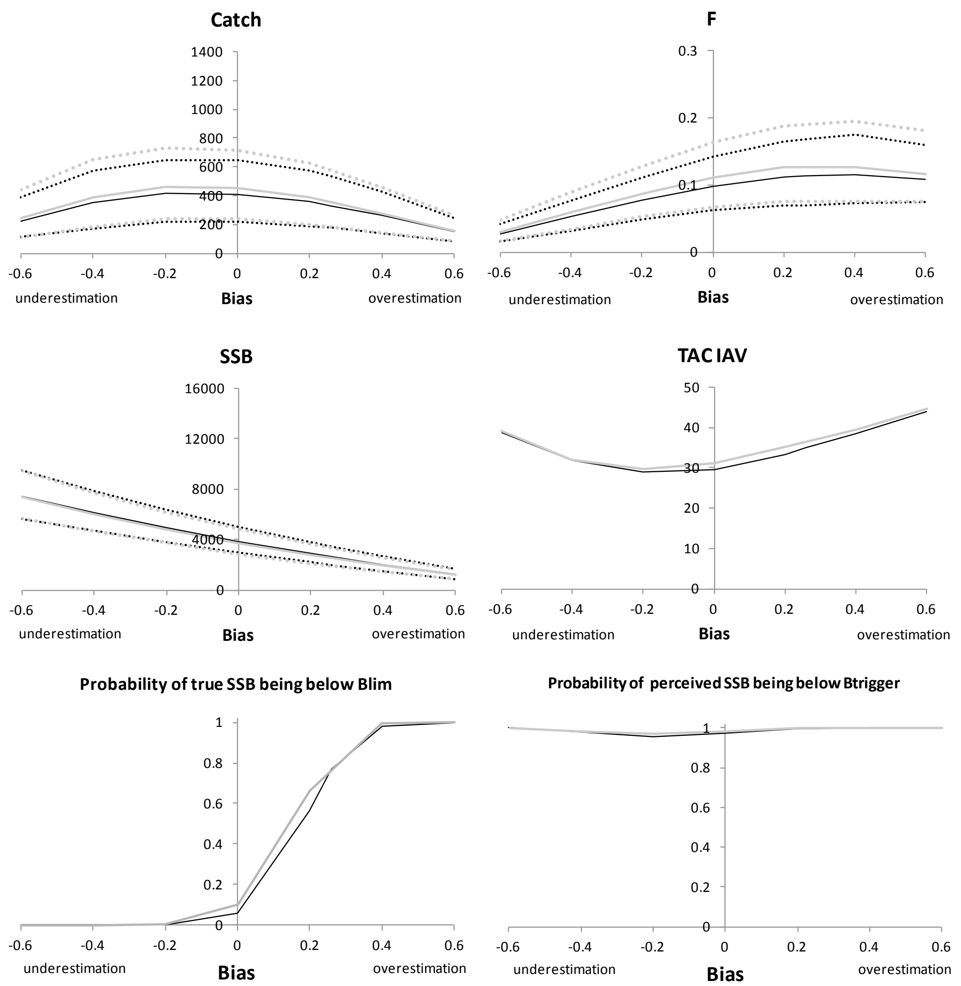

Figure 7.7.3.2.13. Norwegian spring spawning herring. Negative bias means underestimating the stock and positive bias means overestimating the stock. The plots show the short-term average (over the first 5 years) applying the current long-term management plan (black lines), and the current management plan amended with F_{MSY} = 0.15 (grey lines). Original figure in WKBWNSSH.

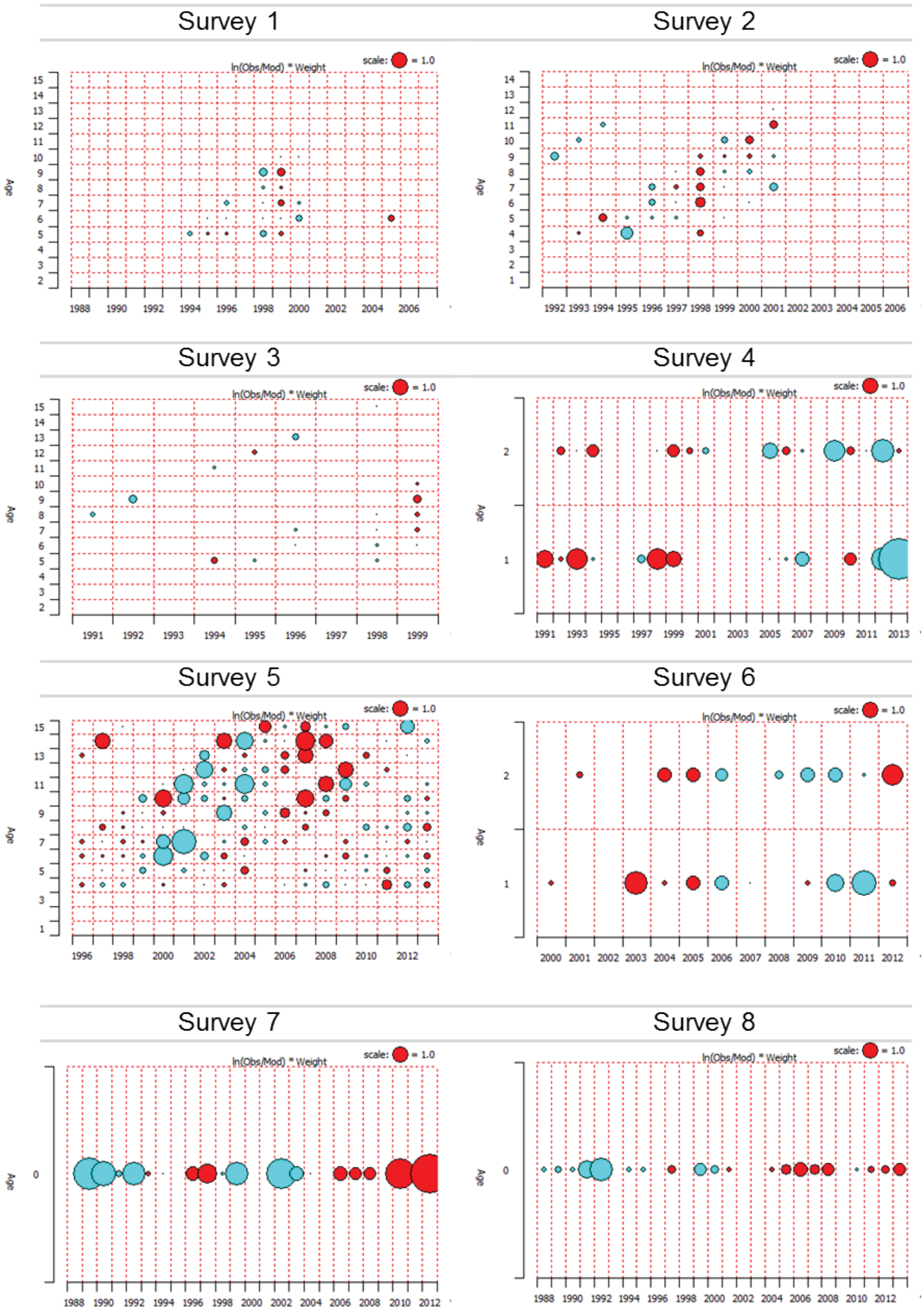

Figure 7.7.3.3. Norwegian spring-spawning herring. Residual sum of squares in the surveys separately from TASACS in 2008 - 2012.

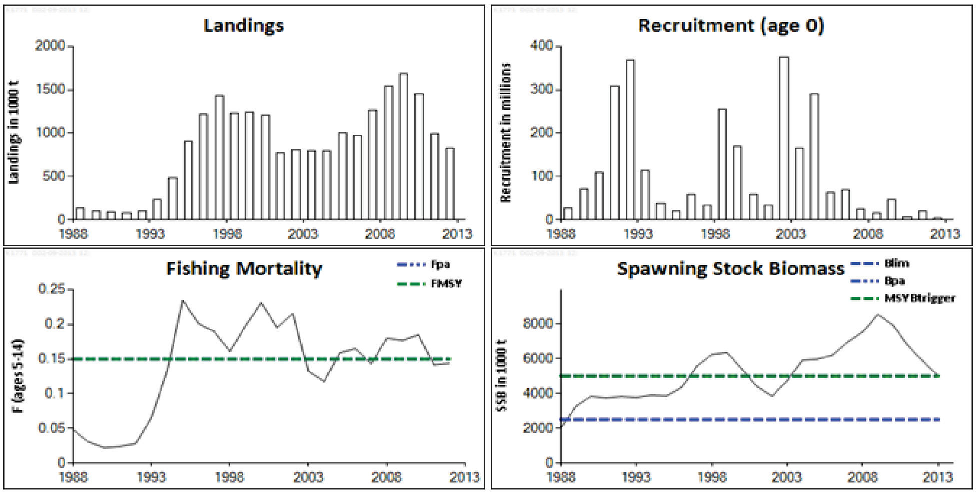

Figure 7.7.3.5. Norwegian spring-spawning herring. Standard plots from final assessment (TASACS VPA) in 2013.

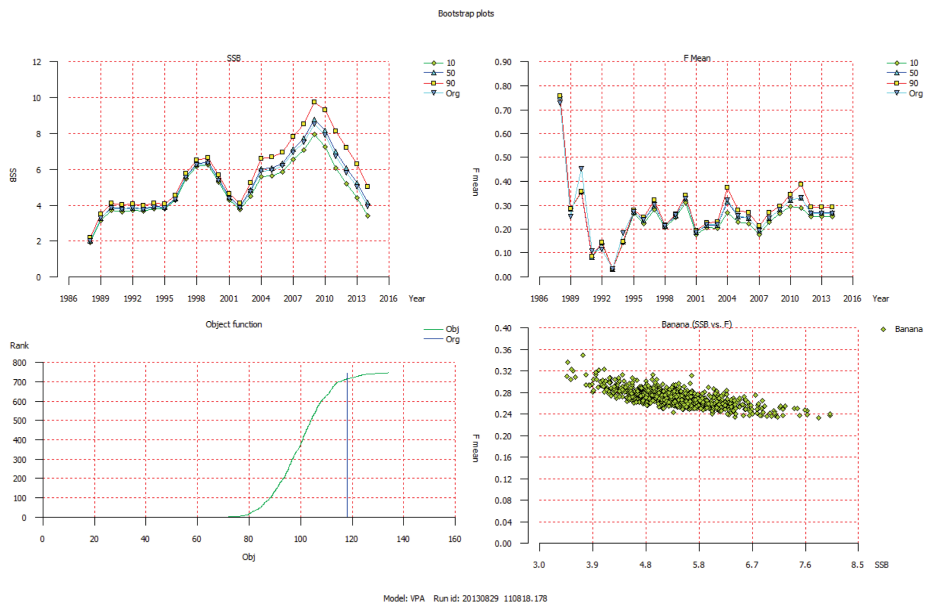

Figure 7.7.4.1. Norwegian spring-spawning herring. Percentiles for spawning stock biomass (top left), mean F 5-10 (top right), SSQ (bottom left) and "Banana"-plot (bottom right) from bootstrap results for final assessment.

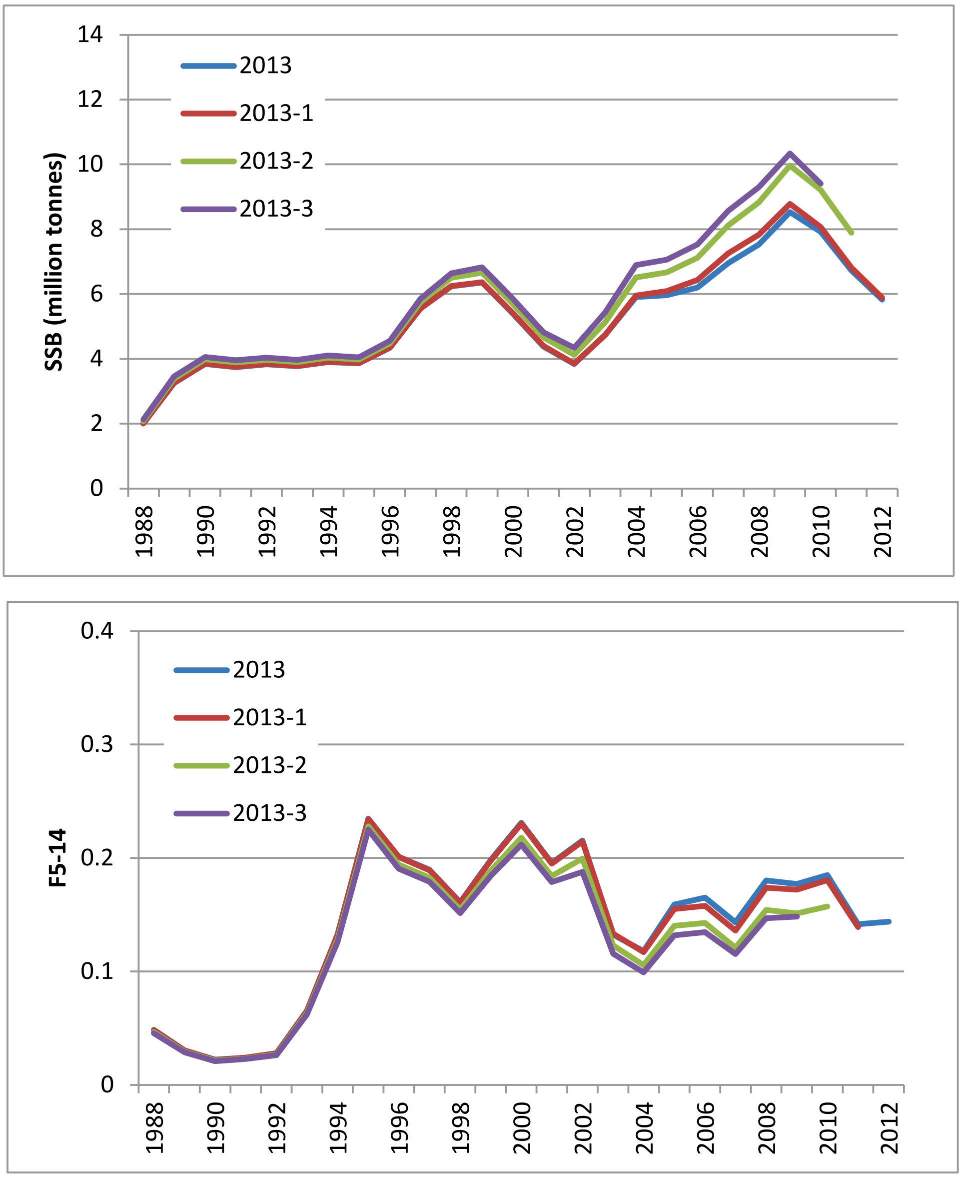

Figure 7.7.5.1 Norwegian spring-spawning herring. Retrospective run for SSB and F.

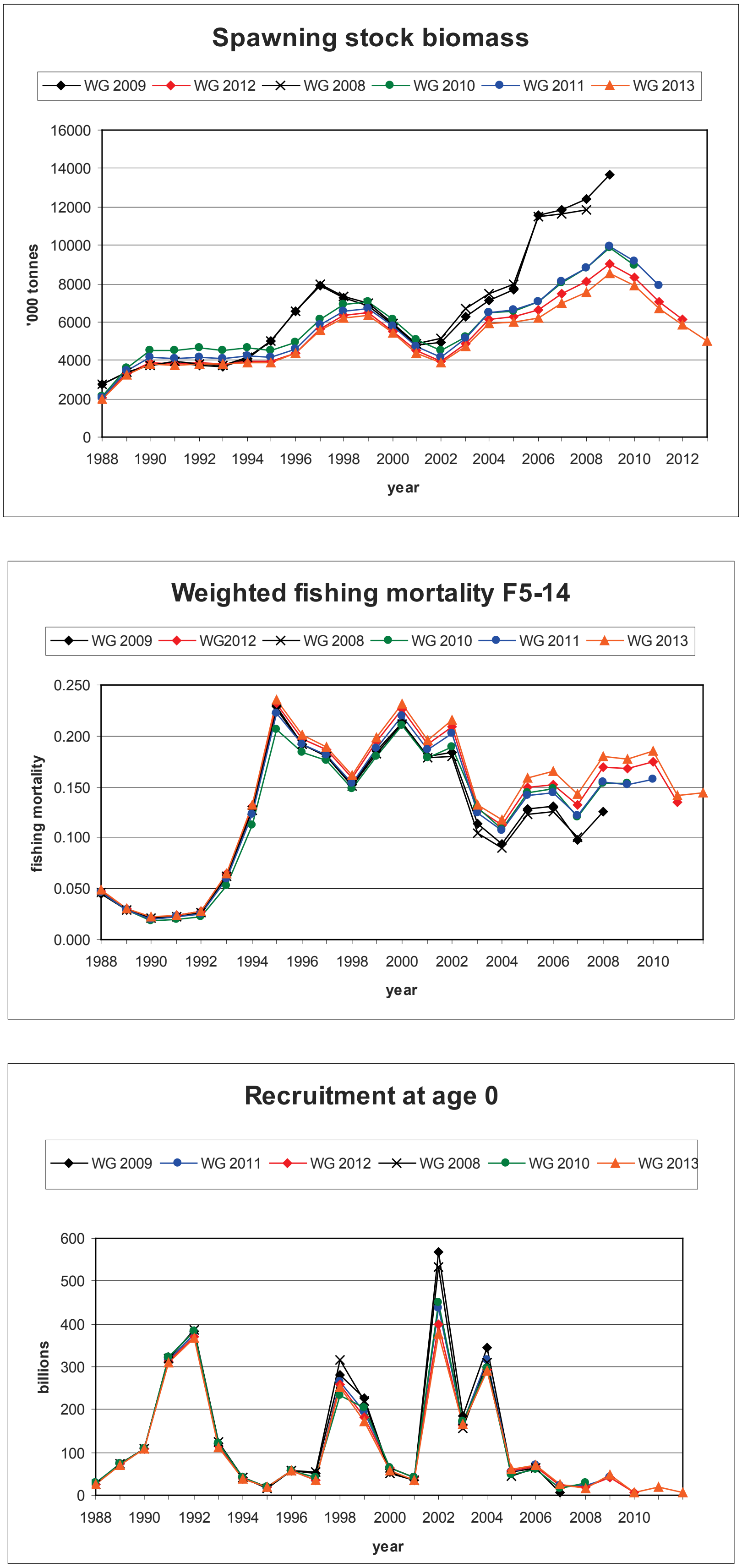

Figure 7.12.1. Norwegian spring spawning herring. Comparisons of spawning stock, weighted fishing mortality F5-14 and recruitment at age 0 with previous assessments.

8 Blue Whiting – Subareas I-IX, XII and XIV

Blue whiting (*Micromesistius poutassou*) is a small pelagic gadoid that is widely distributed in the eastern part of the North Atlantic. The highest concentrations are found along the edge of the continental shelf in areas west of the British Isles and on the Rockall Bank plateau where it occurs in large schools at depths ranging between 300 and 600 meters but is also present in almost all other management areas between the Barents Sea and the Strait of Gibraltar and west to the Irminger Sea. Adults reach maturation at 2–7 years old and undertake long annual migrations from the feeding grounds to the spawning grounds. Most of the spawning takes place between March and April, along the shelf edge and banks west of the British Isles. Juveniles are abundant in many areas, with the main nursery area believed to be the Norwegian Sea. See the stock Annex for further details on stock biology.

8.1 ICES advice in 2012

ICES estimates a historical low landings and fishing mortality at 0.04 in 2011, in combination with an increase in recruitment since 2010, have stopped the steep decline in SSB since 2004. SSB has increased by one million tonnes from 2011 to 2012 (3.8 million tonnes) and is above Bpa at the beginning of 2012. An increase in recruitment has been observed for the last two years, but the absolute recruitment strength is uncertain

ICES advises on the basis of the management plan agreed by Norway, the EU, the Faroe Islands, and Iceland, that catches in 2013 should be no more than 643 000 tonnes.

8.2 The fishery in 2012

The main fisheries on blue whiting were targeting spawning and post-spawning fish in the EU region, International waters west of Porcupine Bank/Rockall Bank areas, west of Scotland and the Faroese region (Figure 8.2.2-3). Most of the catches (93%) were taken in the first two quarters of the year. The multi-national fleet currently targeting blue whiting consists of several types of vessels but the bulk of the catch is caught with large pelagic trawlers. Thirteen countries reported blue whiting landings in 2012. Specific details from some of these fisheries are provided below. Even though the majority of the blue whiting quotas for most national fleets are landed in the first half of the year, detailed information on the timing and location of catches in the current year are not always available by the time of the WGWIDE meeting in September.

8.2.1 Denmark

Danish landings of blue whiting in 2012 were 339 tonnes as the main part of the Danish quota was swapped with other species.

8.2.2 Germany

The vessels targeting blue whiting belong to the pelagic freezer trawler fleet and are owned by a Dutch company and operating under German flag. Depending on season and the economic situation these vessels are targeting other pelagic species in European and international waters. This fleet consists of four large pelagic freezer-trawlers with power ratings between 4 200 and 12 000 hp and crews of about 35 to 40 men. The vessels are purpose built for pelagic fisheries. The catch is pumped into large storage tanks filled with cool water to keep the catch fresh until it is processed. Total landings increased from 278 tonnes in 2011 to 6 238 tonnes in 2012 with the majority of catches taken in areas VIa and VIIc.

8.2.3 Faroe Islands

The Faroese blue whiting quota was 44 019 tonnes in 2012 (including quota transfer from 2011) and the total catch was 43 290 tonnes. Approximately 94 % of the blue whiting was caught within the Faroese EEZ and 6 % in international waters. The majority (98 %) of the blue whiting fishery occurred in winter and early spring, January to May, and began again in December. Location of the fishery shifted between months, began in January within the Faroese EEZ, approximately latitude 60 °N, shifted south, latitude 52 °N to 57 °N, into international waters in March, and moved back north into the Faroese EEZ in April, May and December. The fishing fleet consists of five large trawlers/purse-seiners and one factory freezer utilizing pelagic trawls for fishing and focuses on pre spawning, spawning and post spawning fish.

8.2.4 Iceland

The Icelandic landings in 2012 amounted around 63 000 t. Around 90% of the catches were taken in the Faroes EEZ during March and April. The remaining catches were taken in the Icelandic EEZ during August-December. A small amount was taken in international waters. The catches in the Icelandic EEZ was mainly from a mixed fishery with mackerel and Norwegian spring-spawning herring.

8.2.5 Ireland

The Irish Fishery was confined to the first quarter, with a catch of 7,557t landed. The fishery was concentrated on spawning aggregations to the west and northwest of Ireland. The majority of the catch was from VIa (4539t), and VIIc (934t), followed by small catches in VIb (1658 t) and VIIb (426t). Eight vessels participated in the fishery and there was no difficulty in filling the quota.

8.2.6 Netherlands

The Dutch catches of blue whiting in 2012 were mostly taken in the period February-May in area VIa and VIIc by freezer trawlers. The total catch was 26 000 tonnes. The majority of the catch (95%) was recorded from 12 fishing trips. The remaining catches (5%) were recorded from 9 trips and are by-catch in the fisheries directed to other pelagic species. Estimated discards of blue whiting is 4% in weight originating from non-directed fisheries.

8.2.7 Norway

After the coastal states agreement in 2011 and quota transfers in other international agreements, the Norwegian TAC for 2012 was set to 118 614 t (up to 92 867 t could be taken in the EU zone and up to 16 302 t in the Faroese EEZ). The majority of the Norwegian catches (113 000 t) were taken in a directed pelagic trawl fishery west of the British Isles and south of the Faroe Islands during the first half of the year. The remaining catches were mainly taken by the industrial trawl fleet (which uses both pelagic and demersal trawls) in the Norwegian deeps and Tampen area (east of 4ºW).

8.2.8 Russia

The Russian blue whiting fishery started in the Faroese area the third week of January. One trawler worked there until February 9, and started to fish in the area again on April 1. The vessels left that area on June 12 after having taken 48 thousand tons. Two trawlers returned to the area on December 5. They worked until December 19 to complete the quota of 50 000 tons.

In the central part of Norwegian Sea, the first catches of blue whiting were taken in mid-June. The targeted fishery here was discontinued in early August due to approximation to the agreed catch limit. Afterward, there was a small blue whiting by-catch in the mackerel fishery.

The Russian vessels began to operate in the Porcupine area on February 15. and accumulation of trawlers near the Rockall bank started from March 1. Their number reached 17 by mid-month. The operations were ended there on April 1. This is a week earlier than last year.

8.2.9 Spain

The Spanish blue whiting fishery is carried out mainly by bottom pair trawlers in a directed fishery (approx. one third of the fleet) and by single bottom otter trawlers in a by-catch fishery (approx. two thirds of the fleet). The fleet operates throughout the year. Small quantities are also caught by longliners. These coastal fisheries have trip durations of 1 or 2 days and catches are for human consumption. Thus, coastal landings are driven mainly by market forces, and are rather stable. The fleet operates only in Spanish waters all year round and does not follow any blue whiting migration. The Spanish fleet has decreased from 279 vessels in the early 1990s to 135 vessels in 2008. After a period of decreasing trend, Spanish landings increased in 2011 to a total landing of 10 225 tonnes.

8.2.10 Portugal

Blue whiting is commonly caught as by-catch by the Portuguese bottom-trawl fleets targeting finfish and crustaceans, which comprises around 100 vessels under 30 meters long. Some vessels of the artisanal fishing fleet also catch blue whiting as by-catch, although this is mostly discarded it is rarely used for human consumption in Portugal and there is no market demand for industrial transformation. Total landings in 2012 were about 1955 tonnes.

8.2.11 UK (Scotland)

The Scottish fishery in 2012 took place in Q1 and Q4 with the majority of landings (90%) caught in ICES area VIa. The remainder of landings were caught in areas IVa, VIIb and VIIc. Eight vessels participated in the fishery. The reported landings are the total for all UK vessels landing into Scotland and for all Scottish vessels landing abroad (<1% in 2012).

8.2.12 France

The main French fisheries are west of the British Isles first and second quarter, and south of the Celtic Sea and Bay of Biscay in the fourth quarter. The freezer vessel JOSEPH ROTY 2 is the only French ship targeting blue whiting. The possibility of quota may restrict fishing as in 2011 when it took place in the first quarter. In 2012, the availability of quota was sufficient for activity spread throughout the year."

8.3 Catch data

Total landings in 2012 were about 384 000 tonnes.

Total catches in 2012 were provided by members of the WG. The data provided as catch by rectangle represented more than 96% of the total WG catch in 2012. Total catch by country for the period 1988 to 2012 is presented in Table 8.3.1.1.

After a minimum of 104 000 tonnes in 2011, catches increased to around 384 000 tonnes in 2012. The spatial and temporal distribution in 2012 is quite similar to the distribution in previous years. The majority of catches is coming from the spawning area (Figure 8.3.1.1 B), but compared to previous years, the 2012 catches have a much larger contribution from Division Vb (Figure 8.3.1.2). The temporal allocation of catches has been relatively stable in recent years (Figure 8.3.1.3) however with an increase of the proportion of catches from the second quarter that was also observed in 2012. In the first two quarters catches are taken over a broad area while later in the year catches are mainly taken further north in sub-area II and in the North Sea (Division IVa) and Division V. The proportion of landings originating from the Norwegian Sea has been decreasing steadily over the recent period to less than 10% of the total catch in 2012 (Figure 8.3.1.1B and Table 8.3.1.4).

Discards of blue whiting are thought to be small. Most of these discards are by-catch in fisheries not directed to blue whiting. Most of the blue whiting is caught in directed fisheries for reduction purposes.

8.3.1.1 Sampling intensity

Sampling intensity for blue whiting from the commercial catches by fishery and quarter is shown in Table 8.3.1.2.1, while detailed information on the number of samples, number of fish measured, and number of fish aged by country and quarter is given in Table 8.3.1.2.2 and are presented and described by year, country and area in section 1.3 (1.3 Quality and Adequacy of fishery and sampling data). In total 1143 samples were collected from the fisheries in 2012. 173 206 fish were measured and 15745 were aged. Sampled fish were not evenly distributed throughout the fisheries (Table 8.3.1.2.2). Considering the proportion of samples per catch, the most intensive sampling took place in the mixed fishery with one sample for every 18 tonnes, followed by the southern fishery of Spain and Portugal. Here one sample was taken for every 70 tonnes, and lastly the directed fishery where there was one sample for every 519 tonnes caught. In this context it should be noted that implementation of the EU Collection of Fisheries Data, Fisheries Regulation 1639/2001, requires EU Member States to take a minimum of one sample for every 1000 t landed in their country. As can be seen, no sampling data were submitted by Denmark, Germany and France, all with relatively small landings. Sampling intensity for age and weight of herring and blue whiting are made in proportion to landings according to CR 1639/2001 and apply to EU member states. For other countries there are no guidelines. Current precision levels of the sampling intensity is unknown and the group recommends reviewing the sampling frequency and intensity on a scientific basis and provide guidelines for sampling intensity.

8.3.1.2 Length and age compositions

Data on the combined length composition of the 2012 commercial catch by quarter of the year from the directed fisheries in the Norwegian Sea and from the stock’s main spawning area were provided by the Faroes, France, Iceland, the Netherlands, Norway and Russia (Table 8.3.1.3.1). Length composition of blue whiting varied from 10 to 47 cm, with 95% of fish ranging from 19-35 cm in length, smaller fish if compared with the fish observed last year. The mean length in the fishery was 29.1, which is 1.3 cm smaller than last year, changing the increasing trend in the mean length observed in recent years.

Length compositions of the blue whiting catch and by-catch from "mixed fisheries" in the Norwegian Sea and the North Sea and Skagerrak were presented by Norway (Table 8.3.1.3.2). The catches of blue whiting from the mixed industrial fisheries consisted of fish with lengths of 11-50 cm with 95% of fish ranging from 16-35 cm. The mean length was 28.7 cm, 4 cm longer than last year.

The Spanish and Portuguese data used for length distribution of catches showed a length range of 13-40 cm with 95% of fish ranging from 15 to 28cm (Table 8.3.1.3.3). This distribution is similar as last year. The mean length was 22.9, 1.3 cm longer than the previous year.

The combined age composition for the directed fisheries in the Northern area, i.e. the spawning area and the Norwegian Sea, as well as for the by-catch of blue whiting in "other fisheries" and for landings in the Southern area, were assumed to represent the overall age composition of the total landings for the blue whiting stock. The InterCatch program was used to calculate the total international catch-at-age, and to document how it was done. The catch numbers-at-age used in the stock assessment are given in Table 8.3.1.3.4. The calculation of mean age assigns an age of 10 to all fish in the plus group. Therefore in years of high plus group abundance the mean age could be significantly underestimated. The mean age of the catch (and stock) has been increasing in the period 2001-2010, followed by a drop in 2011, due to the relatively high catches of one and two groups this year. There was also an slight increase to a mean age of 5 years in 2012.

Catch proportions at age plotted in Figure 8.3.1.3.1. Strong year classes can be clearly seen in the early 1980s, 1990 and the late 1990s. Poor recruitment over the recent period is clearly seen in the decreasing proportion of younger fish. This pattern was different in 2011 onwards, where stronger year classes can also be observed.

Catch curves made on the basis of the international catch-at-age (Figure 8.3.1.3.2) indicate a consistent decline in catch number by cohort and thereby reasonably good quality catch-at-age data, especially for year classes since 1995.

8.3.2 Information from the fishing industry

No comprehensive information has been received from the fishing industry this year.

8.3.3 Weight at age

Table 8.3.3.1 and Figure 8.3.3.1 show the mean weight-at-age for the total catch during 1983–2012 used in the stock assessment. Compared to the 2007 mean weights, the values from the succeeding years are higher for most ages, which show that the decreasing trend in mean weight for the period 1995-2005 (2007) has ended.

The weight-at-age for the stock is assumed to be the same as the weight-at-age for the catch.

8.3.4 Maturity and natural mortality

Blue whiting natural mortality and proportion of maturation-at-age is shown in Table 8.3.4.1. See the Stock Annex for further details. A new working document shows a slightly higher proportion mature for ages 2-6 (Heino 2013). These values have not been evaluated and used by the working group.

8.3.5 Fisheries independent data

8.3.5.1 International Blue Whiting spawning stock survey

Background and status

The International Blue Whiting Spawning Stock Survey (IBWSS) is carried out on the spawning grounds west of the British Isles in March-April. The survey started in 2004 and is carried out by Norway, Russia, the Faroe Islands and the EU. This international survey, allowed for broad spatial coverage of the stock as well as a relatively dense amount of trawl and hydrographical stations. The survey is coordinated by WGIPS (ICES CM 2012/ SSGESST:21).

Use of this survey in stock assessment

Indices of age 3-8 from the IBWSS survey have been used in the assessment since 2007.

Quality of the survey

WGIPS decided that in 2013 the survey should be designed to allocate maximum effort in the area normally containing the highest blue whiting concentrations during the survey period (i.e. subarea III, Hebrides). The design was the same as in 2012 and the design is based on variable transect spacing, ranging from 30 nmi in areas containing less dense aggregation (e.g. subarea I, south Porcupine), to 7.5 nmi in the core survey area (subarea III, Hebrides). From past surveys it was evident that huge areas in the west of the Rockall Trough contained, if at all, only sporadic and small blue whiting concentrations. The western borders of the transects in subarea III were therefore reduced to 11ºW in order to allocate more effort on the continental slope. To ensure transect coverage was not replicated, transects were allocated systematically with a random start location.

Norway did not participate in the IBWSS in 2013. However, the planning group was notified already in January that this might happen and were able to take action to secure good coverage with the remaining participating vessels. Due to acceptable - good weather conditions throughout the survey period, the survey resulted in a high quality coverage of the stock. Transects of all vessels were consistent in spatial coverage and timing, delivering full coverage of the respective distribution areas within 19 days

A post-cruise meeting held in Copenhagen 24–26 April 2013 compiled a joint survey report. This will be reviewed in WGIPS in December 2013. The post-cruise meeting concluded that the estimate is a valid extension of the survey time series.

Uncertainties in spawning stock estimates based on bootstrapping of available data have been assessed again in 2013 (Figure 8.3.5.1.1A). At present, only one source of uncertainty is considered namely the spatio-temporal variability in acoustic recordings. Overall mean acoustic density has shown a consistent decrease annually since 2007 to 2011 and is now showing an increasing trend over the last three years. The uncertainty around the biomass is more than could be accounted for from spatial heterogeneity alone and is regarded as statistically significant.

The International spawning stock survey shows good internal consistency for the main age groups in the fishery (Figure 8.3.5.1.1B).

Results

The distribution of acoustic backscattering densities for blue whiting for the last 4 years is shown in Figure 8.3.5.1.2. The highest concentrations of blue whiting were recorded in the Hebrides core area which remains consistent with the results from previous surveys. The blue whiting spawning stock estimates based on the international survey are given in Table 8.3.5.1.1.

The estimated total abundance of blue whiting for the 2013 international survey on the spawning grounds was 3.35 million tonnes, representing an abundance of 27.0x109 individuals. The spawning stock was estimated at 3.16 million tonnes and 24.4x109 individuals. In comparison to the results in 2012, there is a significant increase (55%) in the observed stock biomass.

The stock biomass within the survey area is dominated by age classes 4, 3, 5 and 8 of the 2009, 2010, 2008 and 2005 year classes respectively, comprising 66% of the spawning stock biomass.

Mean length (28.5 cm) and weight (123.9 g) are slightly higher but still lower than in previous years. This can be attributed to the progression of the 3 dominate year classes and increasing contribution of young fish to the total stock biomass. (Figure 8.3.5.1.3). A positive signal of 3 and 4-year old fish (strong 2009 & 2010 year classes) continues to be observed across all areas and the latter is now considered fully recruited to the spawning stock.

8.3.5.2 International ecosystem survey in the Nordic Seas

Background and status

The international ecosystem survey in the Nordic Seas (IESNS) is aimed at observing the pelagic ecosystem with particular focus on Norwegian spring-spawning herring and blue whiting (mainly immature fish) in the Norwegian Sea. Estimates in 2000–2013 are available both for the total survey area and for a “standardized” survey area (Figure 8.3.5.2.1). The latter is more meaningful as the survey coverage has been rather variable in the non-standard areas. However, the historical time series has not been recalculated using the new TS-value for blue whiting, thus the estimates are not directly comparable. The new TS-value gives estimates of roughly 1/3 of the old calculations (i.e. around 3.1 times the current values corresponds to the old value).

The survey is carried out in May since 1995 by the Faroes, Iceland, Norway, and Russia, and since 1997 (except 2002 and 2003) the EU. The high effort in this survey with such a broad international participation allowed for broad spatial coverage as well as a relatively dense net of trawl and hydrographic stations.

Since 2005 this survey has extended into the Barents Sea where the main focus of investigations has been young herring. Low numbers of blue whiting found in the Norwegian bottom trawl survey in this area suggest that this gap would not significantly change the estimate for blue whiting. The survey is coordinated by WGIPS (ICES CM 2012/ SSGESST:21).

Use of this survey in stock assessment

After the benchmark in February 2012 (ICES 2012b) it was decided to not use this survey in the assessment, but it is used as basis for a qualitative estimate of recruitment

Results for blue whiting

The total biomass of blue whiting registered during the May 2013 survey was 0.82 million tons, which is somewhat less than the biomass estimate in 2012. The stock estimate in number for 2013 is 8.6 billion, which is a 40% reduction compared to the 2011 estimate. The main reason for this decrease is that there is very few 1 year old observed in this year's survey, only 0.6 billion. The number of 2 year olds was high, 6.3 billions, which supports the observations from last year that the 2011 year class is above average. This year class constituted to 74% of the total number and 62% of the total biomass.

An estimate was also made from a subset of the data; namely the "standard survey area" between 8°W-20°E and north of 63°N (Figure 8.3.5.2.1). This area has been used as an indicator of the abundance of blue whiting in the Norwegian Sea because the spatial coverage in this area provides a coherent time series with adequate spatial coverage. The age-disaggregated total stock estimate in the "standard area" is presented in Table 8.3.5.2.1, showing that the blue whiting in this index area was also dominated by fish at age 2

The observed distribution of blue whiting in 2013 was similar to 2012 and the main concentrations were observed both in connection with the continental slopes of Norway and south and southwest Iceland and in the open sea in the southern part of the Norwegian Sea (Figure 8.3.5.2.2). It should be noted that the spatial survey design was not intended to cover the whole blue whiting stock during this period.

Age and length distributions from the last five years are shown in Figure 8.3.5.2.3.

8.3.5.3 Norwegian bottom trawl survey in the Barents Sea (BS-NoRu-Q1(Btr))

Background and status

Norway has conducted bottom trawl surveys targeting cod and other demersal fish in the Barents Sea since late 1970s. From 1981 onwards there have been systematically designed surveys carried out during the winter months (usually late January-early March) by at least two Norwegian vessels. In some years the survey has been conducted in co-operation with Russia. Blue whiting are regularly caught as a by-catch species in these surveys, and have in some years been among the numerically dominant species (Heino et al., 2003). This survey has in earlier years given the first reliable indication of year class strength of blue whiting.

Most of the blue whiting catches (or samples thereof) have been measured for body length, but very few age readings are available (from 2004 onwards otoliths are systematically collected). The existing age readings suggest that virtually all blue whiting less than 19 cm in length belong to 1–group and that while some 1–group blue whiting are larger, the resulting underestimation is not significant. An abundance index of all blue whiting and putative 1–group blue whiting from 1981 onwards is given in Table 8.3.5.3.1 and follows methods described in Heino et al. (2003).

In 2013 the 1-group blue whiting were not found in any degree in this survey, suggesting that the 2012-yearclass is not very strong.

Use of this survey in blue whiting assessment

The survey is not used in the assessment, but as basis for a qualitative estimate of recruitment.

8.3.5.4 Other surveys

The stock Annex provides information and time series from surveys covering just a small fraction of the stock area. The International Survey in Nordic Seas and adjacent waters in July-August (IESSNS) is an expansion of the Norwegian Sea summer survey (Stock Annex), however the coverage and main focus has changed. Blue whiting is not main target, but the survey gives useful information of the stock in this period. This survey started in 2009.

8.4 Stock assessment

Blue whiting was benchmarked February 2012 (ICES 2012b) and the SAM model (Nielsen, 2009) was chosen as the default assessment model for the stock. ICES has classified the assessment this year as an update assessment, and no new methods were applied at this year's WG. The results from the SAM model were however compared with the results from methods previously applied for the stock (SMS and XSA). All the models gave similar results. This report will just present the results from the SAM method.

The configuration of the SAM model (see the Stock annex for details) is the same as agreed during the Benchmark WK (ICES 2012b). Residuals from the catch at age observation and survey indices are shown in figure 8.4.1. The catch residuals for 2012 show a tendency for a higher observed catch of older fish than estimated by the model. This might be linked to the shift from the catch in 2011 relatively low proportion of older fish in their catch (mainly from Russian landings) to a mix of both young and old fish in 2012 from international landings. The SAM model allows a gradually change in exploitation pattern , however it might not fully adapt to the changes in the individual years. Residuals from the IBWSS survey showed a clear "year effect" with higher indices for all ages than estimated by the model using all data sources. This however, is often seen time series from acoustic surveys.

The diagnostic output from the SAM model is limited. There is only 13 parameter estimated within the model of which the uncertainties of catch and survey observations are shown in Table 8.4.2. The CV of the catch and of the main age groups in the fishery are low (0.15). The fit for other age groups in both catch and survey is also quite good.

Figure 8.4.2 presents estimated F at age and exploitation pattern for the whole time series. There are no abrupt changes in the exploitation pattern from 2010 to 2012, even though the landings in 2011 were just 19% of the landings in 2010, which might have given a different fishing practice. The estimated rather stable exploitation pattern might be due to the use of correlated random walks for F at age with a high estimated correlation coefficient (0.98).

The retrospective analysis shows a stable estimate of F and SSB (Figures 8.4.3). The use of the SAM option for correlated random walks for F at age (and a high estimated correlation coefficient at 0.98) limits the changes in exploitation pattern when a new year's data are added to the time series, which probably stabilize the estimate of F and SSB. Recruitment in the terminal year is determined from catch data and an assumption on random walk in recruitment as there is no survey indices for age 1 and

2. This gives variable recruitment estimate in the terminal year, but the available short time series indicates that recruitment estimates have been in the range of the final (more converged) model estimate.

Stock summary results with added 95% confidence limits (Figure 8.4.4 and Table 8.4.5) show a decreasing trend in fishing mortality since 2004, with a historical low F in 2011 at 0.04, and an increase in F to 0.103 in. Recruitment decreased substantially in the period 2000-2009 with a resulting strong decreasing SSB up to 2010. SSB has almost doubled from 2010 (2.9 million tonnes) to 2013 (5.5 million tonnes) and is estimated to be above Bpa. The year classes 2005-2008 are at historic low levels, but information from catches and survey show an increase in recruitment since 2009. However, the uncertainty around the recruitment in the most recent year is high.

8.5 Final assessment

Input data are catch numbers at age (Table 8.3.1.3.4), mean weight-at-age in the stock and in the catch (Table 8.3.3.1) and natural mortality and proportion mature in Section 8.3.4. Applied survey data are presented in Table 8.4.1.

This is the second year that the SAM model has been applied for this stock. The model settings can be found in the Stock annex.

The model was run until 2012. The SSB January 1st in 2013 is estimated from survivors and estimated recruits (with an assumption of random walks for recruitment, which in this case give recruitment in 2013 as estimated for 2012). 11% of age-group 1 is assumed mature such the recruitment influence the size of SSB. The key results are presented in Tables 8.4.3–8.4.4 and summarized in Table 8.4.5 and Figure 8.4.4. Residuals of the model fit are shown in Figures 8.4.1.

8.5.1 State of the Stock

SSB has almost doubled from 2010 (2.9 million tonnes) to 2013 (5.5 million tonnes) and is clearly above Bpa (2.25 million tonnes). This increase is due to historical low F in 2011 and 2012 in combination with an higher recruitment (age 1) since 2010. The uncertainty around the recruitment in the most recent year is high.

The year classes 2005-2008 are in the very low end of the historical recruitments, but the 2009 and 2010 year class are estimated higher. Information on the 2011 and 2012 year classes is uncertain, but estimates indicated recruitment at similar level as the two previous years.

8.6 Biological reference points

As a response to a special request from NEAFC, ICES re-evaluated in May 2013 (ICES advice, 2013) the reference points for the stock. ICES concluded that Blim and Bpa should remain unchanged. Fpa and Flim were undefined. Equilibrium stochastic simulations have been used to give a new value for Flim = 0.48. On the basis of this and the uncertainty in the assessment, a corresponding value for Fpa = 0.32 was derived. Currently MSY advice is based on a management strategy evaluation which used F0.1 as a proxy for FMSY and an MSY Btrigger = Bpa. The new simulations provide estimates of FMSY = 0.30. There are no scientific reasons to reduce MSY Btrigger below Bpa, and no estimates of MSY Btrigger are above Bpa. Under these circumstances it is proposed that Bpa be retained as MSY Btrigger for the MSY framework.

In a new request from NEAFC, June 2013, ICES was requested to confirm the suggested reference points, more specifically to confirm:

a) That the value of F0.1 is considered to be 0.22 rather than 0.18, as stated in the advice of September 2012
b) That the value of Fmsy is considered to be 0.30 rather than 0.18, as stated in the advice of September 2012

Figure 8.6.1 shows estimates of F0.1 using the 2013 assessment results. The F0.1 was calculated for each year in the assessment time series, using a three years average of the mean weight at age and exploitation pattern (e.g. the F0.1 for 2011 was estimated use data from 2010, 2011 and 2012). The estimated F0.1 values are in the range 0.18 to 0.23, with values around 0.22 for the most recent years, which confirms the F0.1 (0.22) value suggested by ICES in the May advice.

The variation F0.1 over time is due to both variation in exploitation pattern and mean weight at age, where the variation in mean weight seems to contribute most (Figure 8.6.1).

The ICES advice (ICES advice, 2013) on FMSY at 0.30 was based on stochastic simulation using a "normal recruitment " regime and the criteria of maximum long term yield given a probability of less than 5% that the SSB will be below Blim (see Figure 9.3.3.1.1 in the ICES May advice). The WGWIDE did not re-do the analysis but notes that the yield curve is very flat and the uncertainties around the estimated long term yield is wide. Taking into account the large assessment uncertainties and the very limited gain yield from a higher F, the updated value of F0.1 (0.22) seems more appropriate for management according to F_{MSY} than the value derived from stochastic analysis (0.30).

The present reference points values and their technical basis are:

Reference point	B_{lim}	B_{pa}	F_{lim}	F_{pa}
Value	1.5 mill t	2.25 mill. t	0.48	0.32
Basis	B_{loss}	B_{lim}* exp(1.645* σ), with σ= 0.25.	Equilibrium stochastic simulations, (ICES advice, 2013)	Based on F_{lim} and assessment uncertainties (ICES advice, 2013)

Reference point	F_{MAX}	$F_{0.1}$	F_{MSY}	MSY $B_{trigger}$
Value	NA	0.22	0.22	2.25 mill. t
Basis	F_{MAX} is poorly defined	Yield per recruit (ICES advice, 2013 and WGWIDE, 2013)	F0.1 (WGWIDE, 2013)	B_{pa}

8.7 Short term forecast

8.7.1 Recruitment estimates

The benchmark WKPELA in February 2012 concluded that the available survey indices should be used in a qualitative way to estimate recruitment, rather than using them in a strict quantitative model framework. The WGWIDE has followed this recommendation and investigated several survey time series indices with the potential to give quantitative or semi-quantitative information of blue whiting recruitment.

The International Ecosystem Survey in the Nordic Seas (IESNS) only partially covers the known distribution of recruitment from this stock. Both the 1-group (2012 year class) and 2-group (2011 year class) indices from the survey in 2013 were near the middle of the historical range. The blue whiting estimates from the IESSNS survey in July was not considered reliable due to few samples.

The International Blue Whiting Spawning Stock Survey (IBWSS) is not designed to give a representative estimate of immature blue whiting. However, both the 1- and 2-group indices appear to be fairly consistent with corresponding indices from older ages (Fig. 8.3.5.1.1). Both the 1-group (2012 year class) and 2-group (2011 year class) indices from the survey in 2013 were near the middle of the distributions.

The Norwegian bottom trawl survey in the Barents Sea (BS-NoRu-Q1(Btr)) in February-March 2013, showed that 1-group blue whiting was almost absent (Table 8.3.5.3.1 and Figure 8.3.5.2.3). This index should be used as a presence/absence index, in the way that when blue whiting is present in the Barents Sea this is usually a sign of a strong year-class (Heino et al. 2008), as all known strong year classes have been strong also in the Barents Sea.

The Icelandic bottom trawl survey has a time series from 1996 to present. While this survey is not specifically aimed at demersal species blue whiting juveniles are caught in the deeper regions on the plateau. The recruitment index of age 1 fish was obtained by a cut-off length at 22 cm. The 1-group estimate in 2013 (2012 year class) was at the third quartile (75th percentile) of the distribution.

The Faroese Plateau spring (March) bottom trawl survey has a time series from 1994 to present. While this survey is not specifically aimed at blue whiting, nor has it been used in any assessments, there are some signals in recruitment evident in the time series. An index (number per trawl hour) was created based on a length split at 22 as an estimate of the abundance of age 1 blue whiting. The 1-group estimate in 2013 (2012 year class) was near the third quartile (75th percentile) of the distribution (Figure 8.7.1.1).

In conclusion, the indices from available survey time series indicate that the 2012 year class is around average. Moreover, the new information regarding the 2011 year class suggests that this is at or above average. The WG therefore decided to use the estimate from the assessment for the 2011 year class (approximately at the 70th percentile), and the geometric mean of the whole period (1981-2010) for the 2012 and 2013 year classes (13.46 billion at age 1) (Table 8.7.1.2).

8.7.2 Short term forecast

Due to the uncertainty in the final year estimates of fishing mortality and stock numbers the standard (deterministic) short-term forecast is considered inappropriate for this stock (ICES 2012b). Therefore, stochastic projections are performed, from which short-term projections are extracted. The stochastic projections are carried out by starting at the final year's estimates, using the variance-covariance matrix of those estimates. Due to potential additional information affecting recruitment (qualitative use of recruitment indices, environmental impacts), the terminal stock estimate for age 1 and age 2 could optionally be raised by an input factor. To run the short-term forecast 1000 samples are generated from the estimated distribution of the final years estimates. Those 1000 replicates are then simulated forward according to the model and subject to different scenarios.

Input

Table 8.7.2.1 lists the input data for the short term predictions. Mean weight at age in the stock and mean weight in the catch are the same and are calculated as three year averages (2010–2012). Selection (exploitation pattern) is based on F in 2012 from the most recent assessment. The proportion mature for this stock is assumed constant over the years and values are copied from the assessment input.

As specified in sec 8.7.1 recruitment (age 1) in 2011 and 2012 is assumed as estimated by the SAM model. Recruitment in 2013, 2004 and 2015 are assumed at the long term average (GM 1980-2011).

The "Agreed Records of fisheries consultations between the Faroe Islands, The European Union, Iceland and Norway on the management of blue-whiting in the North East Atlantic in 2011" a limitation of 463 000 tonnes of blue whiting in 2013 was set in accordance to the management plan. F for 2013 is calculated on the basis of this TAC.

Output

A range of predicted catch and SSB options from the short term forecast are presented in Table 8.7.2.2.

The existing management plan has a target F of 0.18 which applies once SSB is above B_{pa} (2.250 million tonnes) on the 1st January of the year in which the TAC is to be set. SSB in 2014 is estimated to be 6.7 million tonnes (above B_{pa}) such that F in 2014 should be 0.18. This will lead to a TAC in 2014 of 949 000 tonnes (an increase at 48%). This is expected to lead to an SSB of 6 958 million tonnes in 2015, which is high above B_{pa}.

Following the ICES MSY framework implies fishing mortality to be at FMSY = 0.22 because SSB in 2013 is above MSY Btrigger. F at 0.22 will give a TAC in 2014 at 1 140 million tonnes (77% increase).

Fishing mortality is below FMSY, therefore the transition scheme towards the ICES MSY framework is not appropriate.

The catch option table (Table 8.7.2.2.) provides a number of combination of F values in 2004 as requested by NEAFC.

The projection 2012-2015 using the existing management plan F shows a substantial uncertainty for the predicted values of recruitment and SSB (Figure 8.7.2.1). Uncertainties in assessment and forecast

The assessments presented this year should be considered to be at the same quality as the assessment presented last year with respect to the absolute estimates of stock metrics, and certain in the conclusion on the steep decline in F in the most recent two years and an increase in SSB. SSB in 2013 is estimated higher than SSB in 2012, but this increase is not statistically significant. Recruitment (age 1) is estimated significantly higher in 2011-2002 than in the years (2007-2009) with the historically low recruitments.

The quality of age readings of blue whiting was evaluated at a workshop (WKARBLUE) on age reading of blue whiting which took place in Bergen, Norway, from 10–14 June 2013 chaired by Jane Amtoft Godiksen and Manuel Meixide. A sample of 158 otoliths was annotated by the participants before the meeting, using WebGR, and a sub-sample of 50 of them were re-annotated at the meeting. Two new samples from Faros and Russia of 50 otoliths each were available at the meeting, together with pictures that were uploaded to WebGR. The results obtained at the workshop show a high discrepancy in age determination among age-readers in all samples with the exception of the Faroese one. This strongly indicates that biased readings might have been present in many cases for the historical data used in the assessment, even for experienced age-readers.

Assessment results for blue whiting are highly dependent on the quality of the only survey that covers the spawning stock (IBWSS). A post-cruise meeting compiled a joint survey report (Anon 2013) where it was concluded that the quality of the survey was high this year. The post-cruise meeting noted that the favourable weather conditions allowed the four survey vessels to successfully cover the entire planned area within the time available and achieved good containment of the stock. Estimated uncertainty around the mean acoustic density is the lowest observed in the time series so far. The working group noted that Norway did not participate in the survey this year. Although this did not significantly affect the quality of the survey in 2013 due favourable conditions, such a reduction in survey effort will decrease the quality of the survey especially during unfavourable weather conditions.

The assessment model SAM was applied for the second time for blue whiting. The two assessment models (SMS and XSA) previously applied for the stock gave a very similar result as SAM and a consistent picture of the state of the stock.

8.7.3 Comparison with previous assessment and forecast

Comparison of the final assessment results from the last 5 years show stable and consistent output, except for the 2010 assessment. In 2010 the survey results from the IBWSS 2010 survey were applied, which gave a too low stock estimate and a corresponding too high F. An evaluation of the survey coverage led to a later exclusion of the 2010 observations.

This year's assessment gave a slightly higher SSB and recruitment for 2011 than the previous assessment

8.8 Management considerations

The assessment shows a moderate uncertainty of the absolute estimate of F and SSB, and a higher uncertainty on the recruiting year-classes. SSB and F are estimated from a fairly good quality catch data and from only one survey giving information on the spawning stock (IBWSS). It is essential that this survey be maintained and it is important to maintain good geographical survey coverage within the agreed time window to avoid increases in assessment uncertainty. A continuous lack of one or more vessels (Norway did not take part of the 2013 survey) will put the survey quality at risk. Due to good planning and favourable weather conditions the implementation of the survey in 2013 resulted in good quality data.

Recruitment (age 1) is estimated significantly higher in 2011-2012 than in the years (2007-2009) with the historically low recruitments. Information from surveys and the fishery suggest a good recruitment in 2013 as well.. The forecast and catch options for 2014 is based on a medium recruitment (age 1) in 2012- 2015 which contribute significantly to the SSB in 2014 and 2015. A TAC derived from the target F at 0.18 (or from F at 0.22) from the management plan is expected to give a SSB substantially higher than Bpa in 2015, even with a slightly overestimation of the recruitment in the most reason years.

8.9 Ecosystem considerations

An extensive overview of ecosystem considerations relevant for blue whiting can be found in the stock annex. A more general overview of the pelagic complex in the NE Atlantic can be found in Chapter 1 of this report.

8.10 Regulations and their effects

Existing TAC are based on annual agreement between the "Coastal States" EU, Norway, Iceland and the Faroe Island. No minimum landing size is associated with blue whiting.

8.10.1 Management plans and evaluations

A meeting was held in 2008 (Anon, 2008) at which a number of potential management strategies for blue whiting were examined through simulations. Following this meeting a new management plan was proposed by the Coastal States. The full text of this plan is also presented in the stock annex. ICES was requested by the coastal states to evaluate this proposed management plan and this evaluation was carried out by WGWIDE in 2008. ICES considers that this plan is precautionary if fishing mortality in the first year is immediately reduced to the fishing mortality that is implied by the harvest control rule. The reduction to F=0.18 was followed by managers for setting the 2010 TAC. Likewise an F=0.05 according to the management plan was applied for 2011. The full text of the management plan is presented in the stock annex.

In May 2013 ICES answered (ICES advice 2013) a request from NEAFC to review a potential new HCR function:

> ICES considered that the current management plan is precautionary. A number of alternative F targets in the range of 0.1–0.35 were evaluated for the current harvest control rule (HCR) form and found to be precautionary up to an F target of 0.32 (corresponding to Fpa), with only a minimal increase in mean TAC for F targets above 0.3.
>
> Inclusion of catch stabilization mechanisms have been tested in the current HCR and are considered precautionary as they do not increase the probability of SSB< Blim above 0.05. Over the entire time period examined there are no significant differences in catch either with or without the stabilizers.
>
> Initial evaluations indicate that a number of options for the newly proposed HCR form (with increasing F at high biomass) have been found to be precautionary. However, these preliminary evaluations are not considered sufficiently robust. Based on the results presented, ICES suggests that a small subset of such rules should be selected and tested further with greater rigour before they are judged suitable for precautionary management. This suggestion led to a new request from NEAFC to evaluate a specified HCR. The conclusion of this new evaluation was not finalised during the WGWIDE meeting
>
> Testing of banking and borrowing scenarios showed very little impact of either extreme banking or borrowing. Allowing a maximum of 10% to be banked or borrowed any year is considered precautionary when used with the existing HCR.

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Nielsen, A. 2012. State-space models as an alternative to overparametrized stock assessment models. In preparation

Table 8.3.1.1. Blue whiting landings (tonnes) by country for the period 1988–2012, as estimated by the Working Group.

Country	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Denmark	18 941	26 630	27 052	15 538	34 356	41 053	20 456	12 439	52 101	26 270	61 523	64 653	57 686	53 333	51 279	82 935
Estonia					6 156	1 033	4 342	7 754	10 982	5 678	6 320					
Faroes	79 831	75 083	48 686	10 563	13 436	16 506	24 342	26 009	24 671	28 546	71 218	105 006	147 991	259 761	205 421	329 895
France		2 191				1 195		720	6 442	12 446	7 984	6 662	13 481	13 480	14 688	14 149
Germany	5 546	5 417	1 699	349	1 332	100	2	6 313	6 876	4 724	17 969	3 170	12 655	19 060	17 050	22 803
Iceland		4 977						369	302	10 464	68 681	160 430	260 857	365 101	287 336	501 493
Ireland	4 646	2 014			781		3	222	1 709	25 785	45 635	35 240	25 200	29 854	17 825	22 580
Japan					918	1 742	2 574									
Latvia					10 742	10 626	2 582									
Lithuania						2 046										
Netherlands	800	2 078	7 750	17 369	11 036	18 482	21 076	26 775	17 669	24 469	27 957	35 843	46 128	73 595	37 529	45 832
Norway	233 314	301 342	310 938	137 610	181 622	211 489	229 643	339 837	394 950	347 311	560 568	528 797	533 280	573 311	571 479	834 540
Poland	10															
Portugal	5 979	3 557	2 864	2 813	4 928	1 236	1 350	2 285	3 561	2 439	1 900	2 625	2 032	1 746	1 659	2 651
Spain	24 847	30 108	29 490	29 180	23 794	31 020	28 118	25 379	21 538	27 683	27 490	23 777	22 622	23 218	17 506	13 825
Sweden ***	1 229	3 062	1 503	1 000	2 058	2 867	3 675	13 000	4 000	4 568	9 299	12 993	3 319	2 086	18 549	65 532
UK (England)****																
UK (Scotland)	5 183	8 056	6 019	3 876	6 867	2 284	4 470	10 583	14 326	33 398	92 383	98 853	42 478	50 147	26 403	27 382
USSR / Russia *	177 521	162 932	125 609	151 226	177 000	139 000	116 781	107 220	86 855	118 656	130 042	178 179	245 198	315 478	290 068	355 319
TOTAL	557 847	627 447	561 610	369 524	475 026	480 679	459 414	578 905	645 982	672 437	1 128 969	1 256 228	1 412 927	1 780 170	1 556 792	2 318 935

Table 8.3.1.1 (continued). Blue whiting landings (tonnes) by country for the period 1988–2012, as estimated by the Working Group.

Country	2004	2005	2006	2007	2008	2009	2010	2011	2012
Denmark	89 500	41 450	56 979	48 659	18 134	248	140	165	340
Estonia	**								
Faroes	322 322	266 799	321 013	317 859	225 003	58 354	49979	16405	43290
France		8 046	18 009	16 638	11 723	8 831	7839	4337	9799
Germany	15 293	22 823	36 437	34 404	25 259	5 044	9108	278	6239
Iceland	379 643	265 516	309 508	236 538	159 307	120 202	87942	5887	63056
Ireland	75 393	73 488	54 910	31 132	22 852	8 776	8324	1195	7557
Japan									
Latvia									
Lithuania			4 635	9 812	5 338				
Netherlands	95 311	147 783	102 711	79 875	78 684	35 686	33762	4595	26526
Norway	957 684	738 490	642 451	539 587	418 289	225 995	194317	20539	118832
Poland									
Portugal	3 937	5 190	5 323	3 897	4 220	2 043	1482	603	1955
Spain	15 612	17 643	15 173	13 557	14 342	20 637	12891	2416	6726
Sweden ***	19 083	2 960	101	464					
UK (England)****									1590
UK (Scotland)	57 028	104 539	72 106	43 540	38 150	173	5496	1331	6305
USSR / Russia *	346 762	332 226	329 100	236 369	225 163	149 650	112553	45841	88303
Uanllocated									3499
TOTAL	2 377 568	2 026 953	1 968 456	1 612 330	1 246 465	635 639	523 832	103 592	384 016

*** From 1992 only Russia**

**** Reported to the EU but not to the ICES WGNPBW. (Landings of 19,467 tonnes)**

***** Imprecise estimates for Sweden: reported catch of 34265 t in 1993 is replaced by the mean of 1992 and 1994, i.e. 2,867 t, and used in the assessment.**

****** From 2012**

Table 8.3.1.2. Blue whiting total landings by country and area for 2012 in tonnes, as estimated by the Working Group.

rea	Denmark	Faroe Islands	France	Germany	Iceland	Ireland	Netherlands	Norway	Portugal	Russia	Spain	UK (England)	UK (Scotland)	unallocated	Grand Total
IIa	84	1249		2	929			1183		17829					21 277
IIb				11			82	29		40					162
IIIa	15														15
IVa	196	215			103		150	4429		520			4		5 617
IVb	45							1							46
IVc															0
IXa									1955		1497			3072	6 524
Va					2930										2 930
Vb		34769			52533			199		44040					131 541
VIa		4488	2637	3963	6108	4539	13066	45934		5536	16		5678		91 965
VIb					25	1658		10182		6578					18 443
VIIb			192			426	4838			9385		1194	5		16 040
VIIc		1591	4988	2238	410	934	8253	46234				235	618		65 502
VIIg										4294					4 294
VIIh			180												180
VIIIa			441								118				559
VIIIb											399				399
VIIIc											4696			427	5 123
VIIId			695												695
VIIj			665	25			115					161			966
VIIk							21	10641							10 662
XII		976								77					1 053
XIVa										4					4
XIVb					18										18
Grand Total	**340**	**43 290**	**9 799**	**6 239**	**63 056**	**7 557**	**26 526**	**118 832**	**1 955**	**88 303**	**6 726**	**1 590**	**6 305**	**3 499**	**384 016**

* Note: the value for area IXa is summed across CN, CS and S subdivisions of this area.

Table 8.3.1.3. Blue whiting total landings of by quarter and area for 2012 in tonnes, as estimated by the Working Group.

Area	1	2	3	4	Total
IIa	196	12275	5979	2827	21277
IIb			16	146	162
IIIa			15		15
IVa	2	2760	2147	709	5617
IVb	1	1	38	5	46
IVc	0		0		0
IXa	1085	1776	1895	1769	6524
Va	24		2180	726	2930
Vb	11807	118484		1250	131541
VIa	33888	58018	3	57	91965
VIb	17317	1126			18443
VIIb	16040				16040
VIIc	65450	52			65502
VIIg	4294				4294
VIIh				180	180
VIIIa	26	8	496	29	559
VIIIb	14	1		384	399
VIIIc	694	1505	1093	1830	5123
VIIId				695	695
VIIj	178	123		665	966
VIIk	10662				10662
XII	1053				1053
XIVa			4		4
XIVb				18	18
Total	162730	196129	13864	11290	384016

Table 8.3.1.2.1. Sampling intensity for blue whiting from the commercial catches by fishery in 2012.

Quarter	Fisheries	Directed	Mixed*	Southern	Total
1	No. of samples	240	108	41	389
	WG Catch	160810	98	1823	162731
2	No. Of samples	268	58	54	380
	WG Catch	190576	2263	3291	196130
3	No. of samples	116	48	49	213
	WG Catch	8 724	2095	3046	13865
4	No. of samples	83	48	30	161
	WG Catch	6 881	389	4020	11290
Total No. of samples		707	262	174	1143
Total WG Catch		366 993	4 843	12 180	384 016
tonnes per sample		519	18	70	336

* Norwegian mixed fishery only.

Table 8.3.1.2.2 Blue whiting. Total landings, No. of samples, No. of fish measured and No. of fish aged by country and quarter for 2012

Country	Quarter	Landings (t)	No. Samples	No. Fish Measured	No. Fish Aged
Denmark	**1**	3			
	2	0			
	3	135			
	4	202			
	Total	**340**			
Faroe Islands	**1**	12546	5	519	500
	2	29027	8	826	778
	3	282			
	4	1436			
	Total	**43290**	**13**	**1345**	**1278**
France	**1**	6545			
	2	1273			
	3	441			
	4	1540			
	Total	9799			
Germany	**1**	3926			
	2	2300			
	3	13			
	4				
	Total	**6239**			
Iceland	**1**	1319			
	2	57971	19	1800	1118
	3	2863			
	4	903	2	132	82
	Total	**63056**	**21**	**1932**	**1200**
Ireland	**1**	6980	7	1446	702
	2	577			
	3				
	4				
	Total	**7557**	**7**	**1446**	**702**
Netherlands	**1**	19914	75	12656	1874
	2	6529			
	3				
	4	82			
	Total	**26526**	**75**	**12656**	**1874**
Norway	**1**	81150	228	6730	843
	2	34762	154	6913	1741
	3	2121	96	5420	550
	4	799	52	2792	305
	Total	**118832**	**530**	**21855**	**3439**
Portugal	**1**	449	5	524	101
	2	609	9	649	165
	3	698	6	468	118
	4	200			
	Total	**1955**	**20**	**1641**	**384**
Russia	**1**	20703	33	4627	405
	2	60331	145	23695	1222
	3	4965	68	10587	1099
	4	2304	77	13561	588
	Total	**88303**	**323**	**52470**	**3314**
Spain	**1**	1374	36	11593	1095
	2	2682	45	19792	1138
	3	2348	43	19205	591
	4	3820	30	29271	730
	Total	**10225**	**154**	**79861**	**3554**
UK (England)	**1**	1521			
	2	69			
	3	0			
	4	0			
	Total	**1590**			
UK(Scotland)	**1**	6301			
	2	0			
	3	0			
	4	4			
	Total	**6305**			
	Grand Total	**384016**	**1143**	**173206**	**15745**

Table 8.3.1.3.1. Blue whiting landings in numbers ('000) by length group (cm) and quarter for the directed fishery in 2012

Length (cm)	Quarter 1	Quarter 2	Quarter 3	Quarter 4	All year
5					
6					
7					
8					
9					
10		115			115
11	1	2 304			2 305
12	1	2 880			2 881
13	286	583			869
14	357	80			436
15	1 917	207	7	4	2 135
16	4 089	3 786	91	37	8 003
17	5 273	7 581	368	208	13 430
18	5 611	11 665	1 514	1 107	19 897
19	4 536	25 966	2 878	3 502	36 882
20	2 554	39 308	3 376	7 791	53 029
21	1 605	27 231	3 355	6 974	39 165
22	2 367	12 170	3 266	6 314	24 117
23	14 665	11 932	2 728	6 006	35 331
24	34 297	28 968	1 582	5 233	70 080
25	57 043	65 784	1 232	3 664	127 722
26	66 011	76 626	1 655	2 897	147 190
27	52 166	59 427	2 563	1 547	115 702
28	37 231	37 590	2 365	1 013	78 199
29	43 563	54 332	1 964	913	100 772
30	68 490	127 085	2 451	832	198 858
31	115 016	172 265	4 252	804	292 337
32	91 356	150 938	4 452	784	247 530
33	71 933	125 471	3 358	656	201 417
34	53 787	83 884	2 462	612	140 745
35	38 692	42 042	1 434	502	82 671
36	15 365	16 875	583	256	33 079
37	7 883	6 672	135	98	14 788
38	4 721	2 153	27	30	6 932
39	2 327	1 530	6	18	3 881
40	633	1 164	5	18	1 820
41	645	491			1 136
42	172	346			517
43	342	370			712
44	128				128
45	243				243
46	20	58			78
47	3				3
48					
49					
50		2			2
51					
52					
53					
54					
55					
TOTAL numbers	805 328	1199 877	48 110	51 821	2105 137

Table 8.3.1.3.2. Blue whiting landings in numbers ('000) by length group (cm) and quarter for the mixed fishery in 2012.

Length (cm)	Quarter 1	Quarter 2	Quarter 3	Quarter 4	All year
5					
6					
7					
8					
9					
10					
11	1				1
12	1				1
13	16	5			21
14	157	15			172
15	469	58	5	1	533
16	358	142	36	7	543
17	157	347	55	35	594
18	75	453	141	126	795
19	44	510	225	201	980
20	22	392	180	201	795
21	14	262	124	172	572
22	8	148	73	173	402
23	18	171	177	88	454
24	37	404	406	39	886
25	54	899	825	27	1 805
26	61	927	899	29	1 916
27	31	719	707	37	1 494
28	22	558	546	25	1 151
29	20	842	939	46	1 847
30	13	1 768	1 922	31	3 734
31	20	2 175	2 394	50	4 639
32	22	1 770	1 961	29	3 782
33	29	1 686	1 880	29	3 624
34	25	1 118	1 279	20	2 442
35	21	732	834	22	1 609
36	10	279	272	7	568
37	7	134	158	3	302
38	3	62	64		129
39	1	44	50		95
40	2	4	13		19
41	2	4	5		11
42					
43			4		4
44	1				1
45					
46	1				1
47					
48					
49					
50		1			1
51					
52					
53					
54					
55					
TOTAL numbers	1 722	16 629	16 174	1 398	35 923

Table 8.3.1.3.3. Blue whiting landings in numbers ('000) by length group (cm) and quarter for the southern fishery in 2012.

Length (cm)	Quarter 1	Quarter 2	Quarter 3	Quarter 4	All year
5					
6					
7					
8					
9					
10					
11					
12					
13		32	1	84	116
14	55	160		599	814
15	28	384	10	2 948	3 370
16	55	897	185	2 564	3 701
17	366	707	811	1 492	3 376
18	1 396	793	1 234	402	3 824
19	2 720	1 231	587	332	4 869
20	3 335	2 673	533	682	7 222
21	5 678	4 457	1 221	1 796	13 152
22	5 750	6 071	2 864	2 819	17 503
23	3 628	7 103	5 060	4 802	20 593
24	2 063	7 173	6 623	5 263	21 123
25	699	4 859	5 251	4 246	15 055
26	476	2 890	3 540	2 750	9 655
27	424	1 068	2 062	2 425	5 978
28	313	761	1 239	1 794	4 106
29	217	334	509	1 018	2 079
30	168	204	314	869	1 555
31	147	136	176	623	1 082
32	139	59	126	120	444
33	159	39	31	82	310
34	64	14	32	14	125
35	18	13	6	27	63
36	10	10	5	29	54
37	3	3	5		11
38		2		2	5
39		1	5		6
40		1	1		3
41					
42					
43					
44					
45					
46					
47					
48					
49					
50					
51					
52					
53					
54					
55					
TOTAL numbers	27 910	42 073	32 431	37 780	140 194

Table 8.3.1.3.4. Blue whiting. Catch at age numbers (millions), and mean age of the catch.

Year\Age	1	2	3	4	5	6	7	8	9	10+	Mean age
1981	258	348	681	334	548	559	466	634	578	1460	6.57
1982	148	274	326	548	264	276	266	272	284	673	6.05
1983	2283	567	270	286	299	304	287	286	225	334	3.57
1984	2291	2331	455	260	285	445	262	193	154	255	3.00
1985	1305	2044	1933	303	188	321	257	174	93	259	3.18
1986	650	816	1862	1717	393	187	201	198	174	398	4.00
1987	838	578	728	1897	726	137	105	123	103	195	3.83
1988	425	721	614	683	1303	618	84	53	33	50	4.03
1989	865	718	1340	791	837	708	139	50	25	38	3.61
1990	1611	703	672	753	520	577	299	78	27	95	3.38
1991	267	1024	514	302	363	258	159	49	5	10	3.42
1992	408	654	1642	569	217	154	110	80	32	12	3.29
1993	263	305	621	1571	411	191	107	65	38	17	3.90
1994	307	108	368	389	1222	281	174	90	79	31	4.57
1995	296	354	422	465	616	800	254	160	60	42	4.62
1996	1893	534	632	537	323	497	663	232	98	83	3.61
1997	2131	1519	904	578	296	252	282	407	104	169	3.17
1998	1657	4181	3541	1045	384	323	303	264	212	86	2.97
1999	788	1549	5821	3461	413	207	151	153	69	140	3.36
2000	1815	1193	3466	5015	1550	514	213	151	58	140	3.55
2001	4364	4486	2962	3807	2593	586	170	97	77	66	2.98
2002	1821	3232	3292	2243	1824	1647	344	169	103	143	3.53
2003	3743	4073	8379	4825	2035	1117	400	121	20	27	3.13
2004	2156	4426	6724	6698	3045	1276	650	249	75	37	3.49
2005	1427	1519	5084	5871	4450	1419	518	249	100	55	3.92
2006	413	940	4206	6151	3834	1719	506	181	68	37	4.15
2007	167	307	1795	4211	3867	2353	936	321	130	89	4.77
2008	409	179	545	2917	3263	1919	736	316	113	127	4.93
2009	61	156	232	595	1596	1157	592	252	89	49	5.40
2010	350	223	160	208	646	992	703	257	70	44	5.29
2011	163	102	64	54	70	116	120	55	26	13	4.43
2012	240	352	663	142	107	203	364	357	212	158	5.06

Table 8.3.1.4. Blue whiting landings (tonnes) from the main fisheries, 1988–2012, as estimated by the Working Group.

Area	Norwegian Sea fishery (SAs 1+2; Divs. Va, XIVa-b)	Fishery in the spawning area (SA XII; Divs. Vb, VIa-b, VIIa-c)	Directed- and mixed fisheries in the North Sea (SA IV; Div. IIIa)	**Total northern areas**	Total southern areas (SAs VIII+IX; Divs. VIId-k)	**Grand total**
1988	55 829	426 037	45 143	**527 009**	30 838	**557 847**
1989	42 615	475 179	75 958	**593 752**	33 695	**627 447**
1990	2 106	463 495	63 192	**528 793**	32 817	**561 610**
1991	78 703	218 946	39 872	**337 521**	32 003	**369 524**
1992	62 312	318 081	65 974	**446 367**	28 722	**475 089**
1993	43 240	347 101	58 082	**448 423**	32 256	**480 679**
1994	22 674	378 704	28 563	**429 941**	29 473	**459 414**
1995	23 733	423 504	104 004	**551 241**	27 664	**578 905**
1996	23 447	478 077	119 359	**620 883**	25 099	**645 982**
1997	62 570	514 654	65 091	**642 315**	30 122	**672 437**
1998	177 494	827 194	94 881	**1 099 569**	29 400	**1 128 969**
1999	179 639	943 578	106 609	**1 229 826**	26 402	**1 256 228**
2000	284 666	989 131	114 477	**1 388 274**	24 654	**1 412 928**
2001	591 583	1 045 100	118 523	**1 755 206**	24 964	**1 780 170**
2002	541 467	846 602	145 652	**1 533 721**	23 071	**1 556 792**
2003	931 508	1 211 621	158 180	**2 301 309**	20 097	**2 321 406**
2004	921 349	1 232 534	138 593	**2 292 476**	85 093	**2 377 569**
2005	405 577	1 465 735	128 033	**1 999 345**	27 608	**2 026 953**
2006	404 362	1 428 208	105 239	**1 937 809**	28 331	**1 966 140**
2007	172 709	1 360 882	61 105	**1 594 695**	17 634	**1 612 330**
2008	68 352	1 111 292	36 061	**1 215 704**	30 761	**1 246 465**
2009	46 629	533 996	22 387	**603 012**	32 627	**635 639**
2011	20 599	72 279	7 524	**100 401**	3 191	**103 592**
2012	24 391	324 545	5678.346	**354 614**	29401.78	**384 016**

Table 8.3.3.1. Blue whiting: Individual mean weight (Kg) at age in the catch

Year\Age	1	2	3	4	5	6	7	8	9	10+
1981	0.052	0.065	0.103	0.125	0.141	0.155	0.170	0.178	0.187	0.213
1982	0.045	0.072	0.111	0.143	0.156	0.177	0.195	0.200	0.204	0.231
1983	0.046	0.074	0.118	0.140	0.153	0.176	0.195	0.200	0.204	0.228
1984	0.035	0.078	0.089	0.132	0.153	0.161	0.175	0.189	0.186	0.206
1985	0.038	0.074	0.097	0.114	0.157	0.177	0.199	0.208	0.218	0.237
1986	0.040	0.073	0.108	0.130	0.165	0.199	0.209	0.243	0.246	0.257
1987	0.048	0.086	0.106	0.124	0.147	0.177	0.208	0.221	0.222	0.254
1988	0.053	0.076	0.097	0.128	0.142	0.157	0.179	0.199	0.222	0.260
1989	0.059	0.079	0.103	0.126	0.148	0.158	0.171	0.203	0.224	0.253
1990	0.045	0.070	0.106	0.123	0.147	0.168	0.175	0.214	0.217	0.256
1991	0.055	0.091	0.107	0.136	0.174	0.190	0.206	0.230	0.232	0.266
1992	0.057	0.083	0.119	0.140	0.167	0.193	0.226	0.235	0.284	0.294
1993	0.066	0.082	0.109	0.137	0.163	0.177	0.200	0.217	0.225	0.281
1994	0.061	0.087	0.108	0.137	0.164	0.189	0.207	0.217	0.247	0.254
1995	0.064	0.091	0.118	0.143	0.154	0.167	0.203	0.206	0.236	0.256
1996	0.041	0.080	0.102	0.116	0.147	0.170	0.214	0.230	0.238	0.279
1997	0.047	0.072	0.102	0.121	0.140	0.166	0.177	0.183	0.203	0.232
1998	0.048	0.072	0.094	0.125	0.149	0.178	0.183	0.188	0.221	0.248
1999	0.063	0.078	0.088	0.109	0.142	0.170	0.199	0.193	0.192	0.245
2000	0.057	0.075	0.086	0.104	0.133	0.156	0.179	0.187	0.232	0.241
2001	0.050	0.078	0.094	0.108	0.129	0.163	0.186	0.193	0.231	0.243
2002	0.054	0.074	0.093	0.115	0.132	0.155	0.173	0.233	0.224	0.262
2003	0.049	0.075	0.098	0.108	0.131	0.148	0.168	0.193	0.232	0.258
2004	0.042	0.066	0.089	0.102	0.123	0.146	0.160	0.173	0.209	0.347
2005	0.039	0.068	0.084	0.099	0.113	0.137	0.156	0.166	0.195	0.217
2006	0.049	0.072	0.089	0.105	0.122	0.138	0.163	0.190	0.212	0.328
2007	0.050	0.064	0.091	0.103	0.115	0.130	0.146	0.169	0.182	0.249
2008	0.055	0.075	0.100	0.106	0.120	0.133	0.146	0.160	0.193	0.209
2009	0.056	0.085	0.105	0.119	0.124	0.138	0.149	0.179	0.214	0.251
2010	0.052	0.064	0.110	0.154	0.154	0.163	0.175	0.187	0.200	0.272
2011	0.055	0.079	0.107	0.136	0.169	0.169	0.179	0.189	0.214	0.270
2012	0.041	0.072	0.098	0.140	0.158	0.172	0.180	0.185	0.189	0.203

Table 8.3.4.1. Blue whiting natural mortality and proportion of maturation-at-age

AGE	0	1	2	3	4	5	6	7–10+
Proportion mature	0.00	0.11	0.40	0.82	0.86	0.91	0.94	1.00
Natural mortality	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20

Table 8.3.5.1.1 Blue whiting stock composition (millions) from the IBSSS for 2004–2013.

Year\Age	1	2	3	4	5	6	7	8	9	10+	Total
2004	1559	5 650	11086	14353	5426	1785	1007	635	367	40	41908
2005	1159	1427	6034	8178	8526	2657	646	233	105	1	28967
2006	1010	1 775	10332	12504	5338	2570	798	261	95	0	34685
2007	552	855	5 270	10606	8001	4501	2348	810	308	135	33461
2008	152	457	1 407	5330	7126	3199	2153	770	137	147	20943
2009	245	620	373	2057	5066	4181	2037	516	125	15	15238
2010*	580	648	212	452	982	2264	2456	1242	352	47	9311
2011	202	2617	942	912	1647	2301	1767	1221	430	31	12075
2012	1178	1832	6678	1013	544	1343	2077	1444	1078	1025	18393
2013	502	1682	7056	7776	3122	1287	1327	1515	867	1892	27026

* The quality of the survey was regarded as not satisfactory

Total stock biomass (kt)

Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
TSB (1000t)	3612	2557	3357	3583	2458	1981	1266	1578	2219	3347

Table 8.3.5.2.1. Estimated blue whiting stock numbers from the International Norwegian Sea ecosystem survey, 2000–2012. The estimates are for the standard area, north of 63°N and between 8°W–20°E.

Year\Age	1	2	3	4	5	6	7	8	9	10	11	Total
2000*	48927	3133	3580	1668	201	5						57514
2001*	85772	25110	7533	3020	2066							123501
2002*	15251	46656	14672	4357	513	445		15		6		81915
2003*	35688	21487	35372	4354	639	201	43	3				97787
2004*	49254	22086	13292	8290	1495	533	83	39				95072
2005*	54660	19904	13828	4714	1886	326	103	43	8	3	11	95486
2006*	570	18300	15324	6550	1566	384	246	80	47	2	8	43077
2007*	21	552	5846	3639	1674	531	178	49	19			12509
2008*	29	75	534	2151	715	287	116	44				3951
2009*	0	14	56	617	963	621	296	84	13			2664
2010*	0	0	0	10	107	165	68	96				446
2011*	1447	3138	1	43	204	226	431	120	84			5694
2012	9425	3142	427	153	87	169	98	31				13532
2013	241	5723	457	81	22	42	62	125	102	26	42	6938

* Using the old TS-value. To compare the results with 2012 all values should be divided by approximately 3.1

Table 8.3.5.3.1 1-group indices of blue whiting from the Norwegian winter survey (late January-early March) in the Barents Sea. (Blue whiting <19 cm in total body length which most likely belong to 1-group.)

	Catch Rate	
Year	All	<19cm
1981	0.13	0
1982	0.17	0.01
1983	4.46	0.46
1984	6.97	2.47
1985	32.51	0.77
1986	17.51	0.89
1987	8.32	0.02
1988	6.38	0.97
1989	1.65	0.18
1990	17.81	16.37
1991	48.87	2.11
1992	30.05	0.06
1993	5.8	0.01
1994	3.02	0
1995	1.65	0.10
1996	9.88	5.81
1997	187.24	175.26
1998	7.14	0.21
1999	5.98	0.71
2000	129.23	120.90
2001	329.04	233.76
2002	102.63	9.69
2003	75.25	15.15
2004	124.01	36.74
2005	206.18	90.23
2006	269.2	3.52
2007	80.38	0.16
2008	17.03	0.04
2009	4.5	0.01
2010	3.3	0.08
2011	1.48	0.01
2012	127.89	126.83
2013	39.54	2.33

Table 8.4.1. Blue Whiting: Survey indices used in the assessment.

IBWSS

	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8
2004	11086	14353	5426	1785	1007	635
2005	6034	8178	8526	2657	646	233
2006	10332	12504	5338	2570	798	261
2007	5270	10606	8001	4501	2348	810
2008	1440	5668	6516	3845	2122	1050
2009	373	2057	5066	4181	2037	516
2010	-1	-1	-1	-1	-1	-1
2011	942	912	1647	2301	1767	1221
2012	6678	1013	544	1343	2077	1444
2013	7776	3122	1287	1327	1515	867

Table 8.4.2. Blue Whiting: Estimated observation noise.

Index	Age	sd of log(observation noise) ~ CV
Catch	1	0.43
Catch	2	0.29
Catch	3-8	0.15
Catch	9-10	0.44
IBWSS	3	0.36
IBWSS	4-6	0.24
IBWSS	7-8	0.31

Table 8.4.3. Blue whiting. Estimated fishing mortalities.

Year\Age	1	2	3	4	5	6	7	8	9+	3-7
1981	0.070	0.117	0.174	0.219	0.262	0.347	0.376	0.477	0.484	0.275
1982	0.056	0.094	0.140	0.179	0.209	0.279	0.303	0.383	0.386	0.222
1983	0.067	0.110	0.164	0.209	0.244	0.334	0.362	0.451	0.448	0.263
1984	0.081	0.132	0.198	0.255	0.302	0.414	0.441	0.544	0.537	0.322
1985	0.085	0.135	0.207	0.272	0.330	0.444	0.466	0.573	0.565	0.344
1986	0.109	0.171	0.266	0.365	0.453	0.588	0.615	0.756	0.746	0.457
1987	0.098	0.152	0.243	0.337	0.421	0.550	0.572	0.698	0.680	0.425
1988	0.097	0.149	0.249	0.340	0.437	0.580	0.584	0.705	0.676	0.438
1989	0.110	0.169	0.296	0.400	0.508	0.667	0.682	0.815	0.776	0.511
1990	0.111	0.169	0.309	0.419	0.528	0.683	0.723	0.847	0.809	0.532
1991	0.054	0.083	0.156	0.215	0.269	0.337	0.362	0.417	0.400	0.268
1992	0.047	0.070	0.139	0.193	0.234	0.283	0.312	0.365	0.349	0.232
1993	0.041	0.061	0.127	0.176	0.212	0.250	0.278	0.328	0.313	0.209
1994	0.037	0.055	0.119	0.166	0.199	0.230	0.259	0.310	0.291	0.195
1995	0.046	0.068	0.153	0.221	0.252	0.291	0.328	0.399	0.368	0.249
1996	0.056	0.082	0.189	0.282	0.303	0.359	0.400	0.494	0.450	0.306
1997	0.053	0.078	0.185	0.283	0.294	0.350	0.388	0.483	0.438	0.300
1998	0.070	0.105	0.252	0.397	0.407	0.487	0.532	0.665	0.592	0.415
1999	0.059	0.088	0.214	0.347	0.355	0.426	0.451	0.567	0.504	0.359
2000	0.075	0.112	0.270	0.445	0.479	0.575	0.589	0.728	0.652	0.472
2001	0.070	0.105	0.252	0.420	0.472	0.563	0.562	0.688	0.623	0.454
2002	0.074	0.109	0.260	0.438	0.519	0.628	0.617	0.739	0.670	0.492
2003	0.068	0.099	0.239	0.406	0.500	0.591	0.578	0.665	0.607	0.463
2004	0.076	0.110	0.264	0.454	0.586	0.686	0.681	0.747	0.687	0.534
2005	0.071	0.099	0.238	0.422	0.562	0.649	0.649	0.696	0.639	0.504
2006	0.057	0.081	0.192	0.344	0.472	0.543	0.540	0.568	0.520	0.418
2007	0.057	0.080	0.186	0.338	0.477	0.556	0.556	0.569	0.521	0.423
2008	0.051	0.073	0.166	0.300	0.432	0.501	0.508	0.508	0.467	0.381
2009	0.031	0.045	0.105	0.182	0.268	0.311	0.323	0.317	0.286	0.238
2010	0.024	0.035	0.080	0.136	0.203	0.238	0.252	0.239	0.215	0.182
2011	0.005	0.008	0.018	0.030	0.045	0.053	0.056	0.053	0.048	0.040
2012	0.013	0.020	0.046	0.075	0.113	0.136	0.146	0.139	0.124	0.103

Table 8.4.4. Blue Whiting. Estimated stock numbers at age (million).

Year\Age	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10+**
1981	4005	3580	4718	2035	2456	2084	1650	1808	1467	3227
1982	5379	2943	2645	3266	1538	1401	1199	945	902	2200
1983	21274	4248	1995	1792	1851	1169	954	809	545	1536
1984	20645	16420	2739	1287	1273	1355	779	521	425	1040
1985	10100	15142	10713	1571	778	908	758	443	251	743
1986	7018	6544	9801	5885	1009	481	497	406	226	517
1987	8632	4896	4127	6689	2569	419	247	244	163	296
1988	6206	6557	3389	2879	3712	1253	207	117	95	177
1989	8521	4524	5020	2508	2148	1631	375	98	50	116
1990	17663	5921	2917	2674	1479	1215	595	141	38	73
1991	9249	14887	4185	1769	1488	851	536	186	41	39
1992	7167	7687	13164	3345	1240	784	464	291	101	43
1993	5309	5267	5466	10069	2320	968	505	275	161	81
1994	7378	3693	3693	3392	6750	1526	767	351	181	141
1995	9762	5587	3150	2533	2766	3783	1013	521	215	191
1996	29064	7519	4001	2299	1521	1776	2213	625	298	240
1997	45947	22544	5610	2500	1370	1010	994	1172	304	302
1998	28460	39036	17210	3489	1359	907	724	569	578	299
1999	21317	21574	29297	10756	1746	737	488	366	231	397
2000	36947	16289	16535	16063	4543	1146	476	303	163	312
2001	58003	30069	13270	11018	7580	1732	503	224	132	203
2002	48984	45037	19115	8040	5390	3503	778	286	104	160
2003	52483	40833	37845	14133	5153	2758	1188	305	97	102
2004	34726	40467	31078	22432	7504	2663	1333	563	137	89
2005	20419	27045	28064	18384	11040	3352	1107	513	217	97
2006	7595	15871	24791	21041	10019	4533	1394	465	214	132
2007	4156	5582	13151	16971	11139	5488	2311	774	241	183
2008	5142	3116	4453	11084	9694	5278	2198	965	339	221
2009	5666	3591	2400	3953	7153	5005	2429	951	431	264
2010	18774	4926	2441	1969	3548	4695	2985	1353	511	378
2011	27099	16668	3620	1776	1799	2709	2741	1479	846	534
2012	21834	22231	15919	2508	1169	1688	2613	2521	1260	1137
2013	13463*	17628	18812	13138	2564	1115	1328	1873	1796	1734

*GM(1981-2010)

Table 8.4.5. Blue whiting. Estimated recruitment in millions, total stock biomass (TBS) in 1000 tonnes, spawning stock biomass (SSB) in 1000 tonnes, and average fishing mortality for ages 3 to 7 (F37).

Year	Recruits	Low	High	TSB	Low	High	SSB	Low	High	F37	Low	High
1981	4005	2499	6419	3416	2782	4194	2917	2335	3644	0.275	0.217	0.350
1982	5379	3343	8655	2816	2323	3415	2320	1884	2856	0.222	0.176	0.280
1983	21274	13372	33846	3079	2519	3763	1903	1590	2278	0.263	0.212	0.326
1984	20645	13188	32321	3358	2709	4164	1849	1557	2196	0.322	0.263	0.394
1985	10100	6473	15757	3478	2863	4225	2233	1870	2667	0.344	0.284	0.417
1986	7018	4573	10771	3236	2753	3804	2381	2025	2799	0.457	0.380	0.550
1987	8632	5630	13235	2772	2362	3253	1916	1638	2242	0.425	0.351	0.513
1988	6206	4029	9558	2376	2031	2780	1614	1392	1870	0.438	0.362	0.530
1989	8521	5521	13149	2393	2026	2826	1550	1338	1797	0.511	0.423	0.617
1990	17663	11219	27810	2429	1965	3003	1341	1143	1574	0.532	0.430	0.658
1991	9249	5837	14655	3144	2477	3991	1732	1403	2139	0.268	0.210	0.341
1992	7167	4568	11245	3653	2928	4557	2533	2027	3166	0.232	0.182	0.296
1993	5309	3366	8376	3527	2865	4342	2610	2110	3229	0.209	0.165	0.264
1994	7378	4736	11494	3345	2762	4051	2498	2054	3038	0.195	0.155	0.245
1995	9762	6275	15187	3338	2788	3998	2283	1924	2709	0.249	0.200	0.309
1996	29064	18777	44985	3749	3076	4570	2178	1856	2556	0.306	0.249	0.377
1997	45947	29732	71005	5537	4384	6993	2471	2081	2934	0.300	0.245	0.367
1998	28460	18554	43654	7039	5691	8706	3753	3111	4527	0.415	0.342	0.503
1999	21317	13778	32980	7460	6158	9036	4597	3787	5581	0.359	0.296	0.435
2000	36947	23836	57271	7460	6209	8962	4295	3673	5023	0.472	0.391	0.568
2001	58003	37506	89700	9157	7502	11177	4676	4000	5467	0.454	0.377	0.547
2002	48984	31526	76109	10201	8329	12494	5299	4502	6237	0.492	0.408	0.594
2003	52483	33871	81321	12262	10158	14802	7167	6035	8512	0.463	0.385	0.557
2004	34726	21918	55020	10864	9107	12960	7039	5999	8259	0.534	0.442	0.645
2005	20419	12832	32493	8842	7354	10630	6212	5245	7358	0.504	0.412	0.617
2006	7595	4762	12114	8187	6838	9800	6312	5297	7522	0.418	0.339	0.516
2007	4156	2585	6680	6059	5059	7256	5045	4219	6034	0.423	0.335	0.534
2008	5142	3160	8367	4584	3757	5592	3802	3120	4633	0.381	0.294	0.495
2009	5666	3358	9560	3616	2862	4570	2920	2310	3690	0.238	0.179	0.316
2010	18774	11118	31702	4143	3160	5432	2908	2234	3785	0.182	0.135	0.245
2011	27099	15296	48009	5309	3880	7265	3021	2297	3973	0.040	0.030	0.054
2012	21834	9410	50665	6293	4580	8647	4164	3174	5463	0.103	0.078	0.136
2013							5532*	4009*	7633*			

*using mean weights from 2012

Table 8.7.1.1. Blue Whiting. Indices of blue whiting at age 1from the Icelandic March bottom trawl survey 1996-2013.

Year	Index for age 1
1996	6.5
1997	3.4
1998	1.1
1999	6.3
2000	9
2001	5.2
2002	14.2
2003	15.4
2004	8.9
2005	8.3
2006	30.4
2007	3.9
2008	0.1
2009	1.6
2010	0.2
2011	10.8
2012	29.9
2013	11.7

Table 8.7.1.2. Blue Whiting. Upper part: Recruitment candidates (R_1, number at age 1, millions) to be used in the forecast section. Lower part: Geometric means of age 1 blue whiting from the final assessment run.

Year	Number at age 1
2012	21834
2013	13463
2014	13463
Year range	Geometric mean
1981-1995, 2006-2010	7944
1981-2010	13463
1996-2005	35484

Table 8.7.2.1. Blue Whiting. Input to short term projection (median values for exploitation pattern and stock numbers).

Age	Mean weight in the stock (kg)	Mean weight in the catch (kg)	Proportion mature	Natural mortality	Exploitation pattern	Stock numbers 2013 (millions)
1	0.050	0.050	0.11	0.20	0.130	13463
2	0.072	0.072	0.40	0.20	0.191	17628
3	0.105	0.105	0.82	0.20	0.445	18812
4	0.143	0.143	0.86	0.20	0.741	13138
5	0.161	0.161	0.91	0.20	1.108	2564
6	0.168	0.168	0.94	0.20	1.312	1115
7	0.178	0.178	1.00	0.20	1.395	1328
8	0.187	0.187	1.00	0.20	1.325	1873
9	0.201	0.201	1.00	0.20	1.189	1796
10	0.248	0.248	1.00	0.20	1.189	1734

Table 8.7.2.2. Blue whiting. Forecasts.
Basis: F(2013) = 0.14 (catch constraint = 643 = TAC). SSB(2014) = 6715. R(2013), R(2014) and R(2015) = GM(1981-2010) = 13463 million at age 1.

Rationale	Catch (2014)	Basis	F 2014	SSB (2015)	% SSB change	% TAC change
Management plan	949	F = 0.18 for SSB(2014)>2250	0.18	6958	4	48
NEAFC request	1140	Management plan, F=0.22	0.22	6767	1	77
NEAFC request	1279	Management plan, F=0.25	0.25	6635	-1	99
NEAFC request	1502	Management plan, F=0.30	0.30	6422	-4	134
MSY framework	1140	FMSY=F0.1	0.22	6767	1	77
Fpa 0.32	1588	Fpa	0.32	6333	-6	144
Flim 0.48	2232	Flim	0.48	5723	-15	247
Zero catch	0		0.00	7877	17	-100
1.00*F(2012)	562	1.00*F(2012)	0.10	7336	9	-13
0.50*F(2013)	401	0.50*F(2013)	0.07	7484	11	-38
Status quo F	777	1.00*F(2013)	0.15	7131	6	21
1.50*F(2013)	1129	1.50*F(2013)	0.22	6779	1	75
2.00*F(2013)	1460	2.00*F(2013)	0.29	6465	-4	127

Cathes in 1000 tonnes and numbers in millions

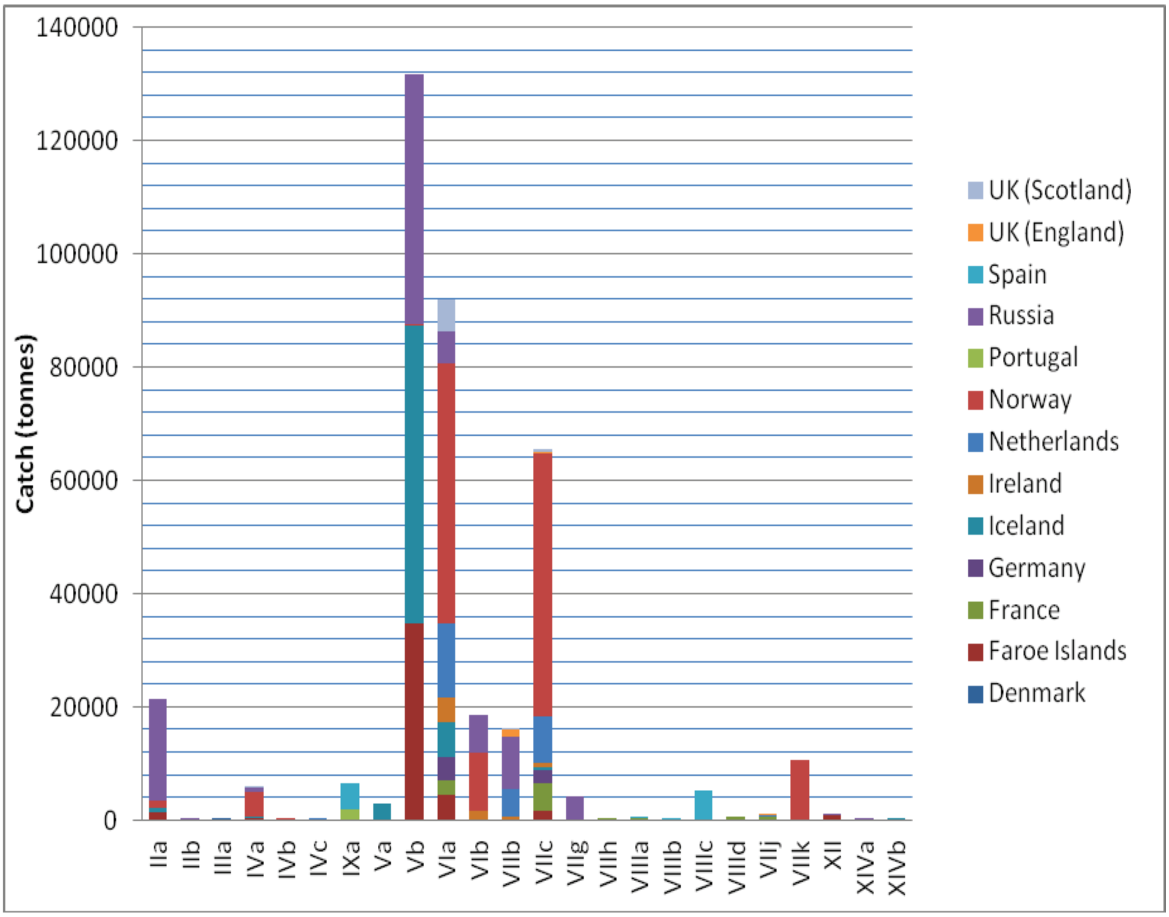


Figure 8.2.1. Blue whiting landings (tonnes) in 2012 presented by ICES area and country.

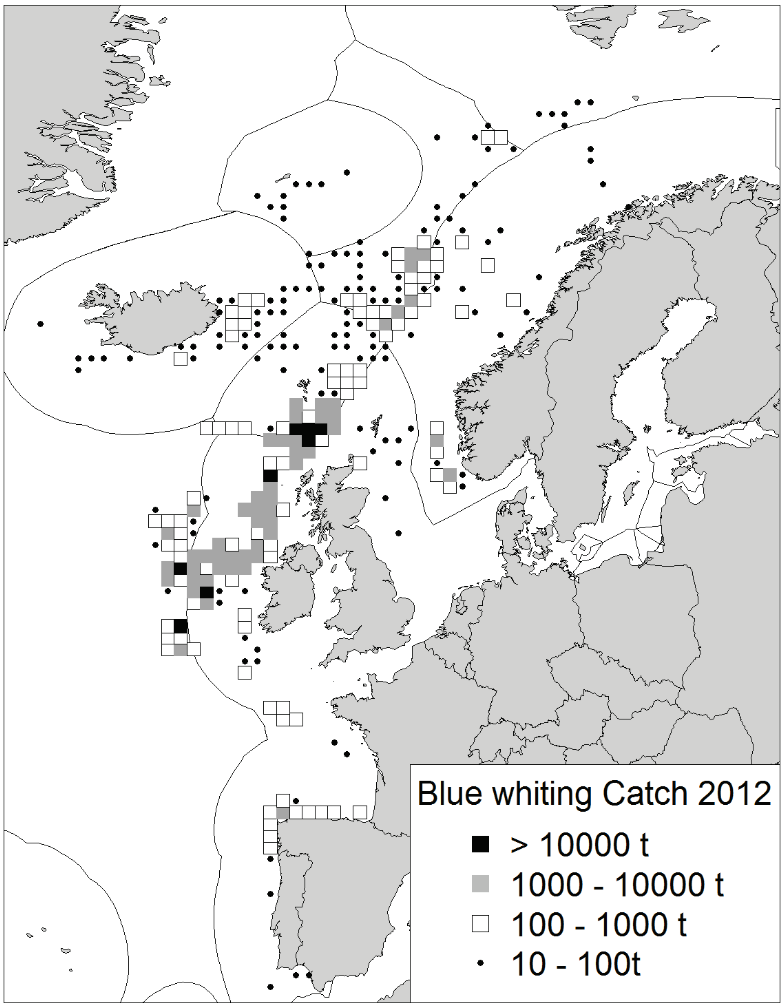


Figure 8.2.2. Total blue whiting catches (t) in 2012 by ICES rectangle. Catches below 10 t are not shown on the map. The catches on the map constitute 98% of the total catches.

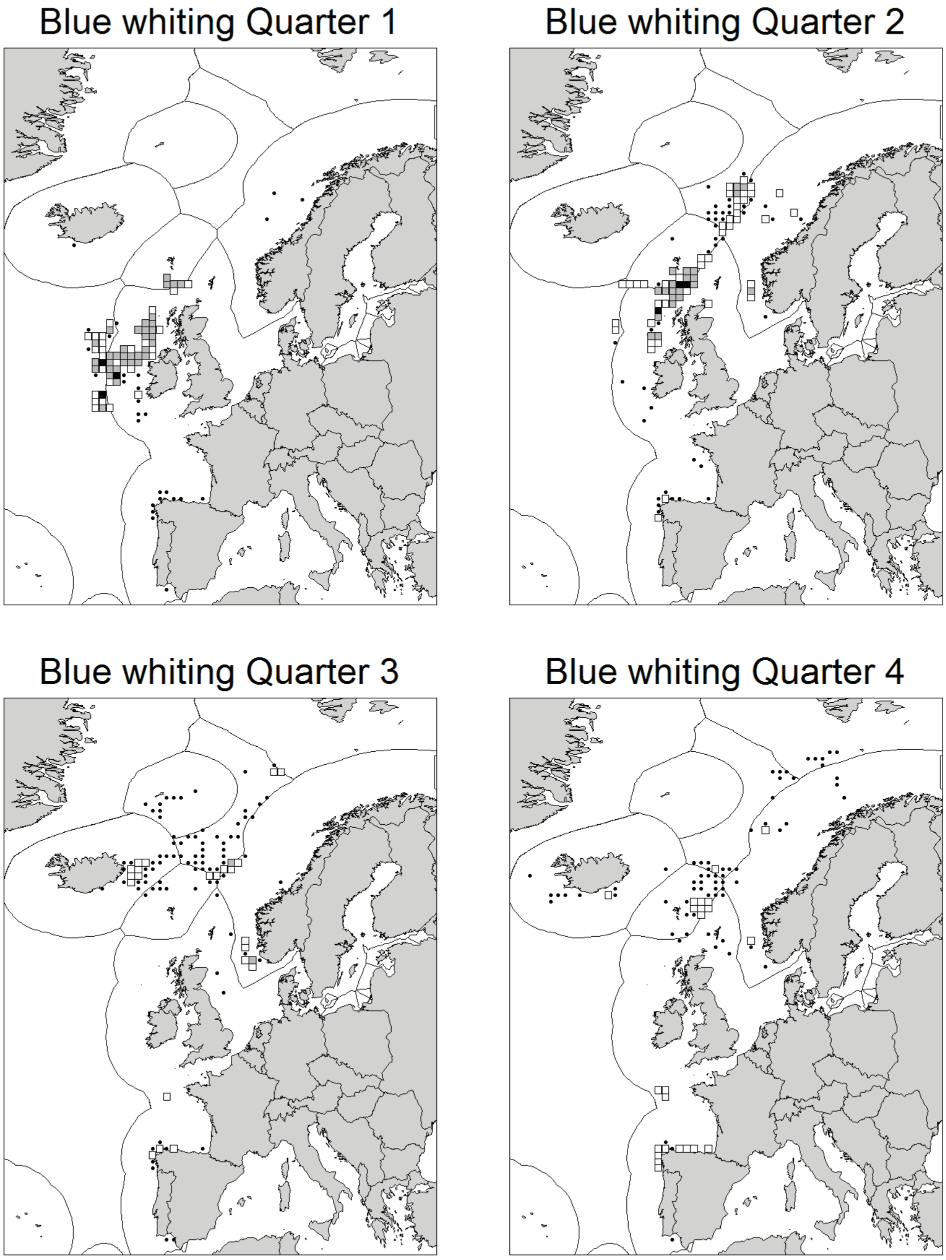
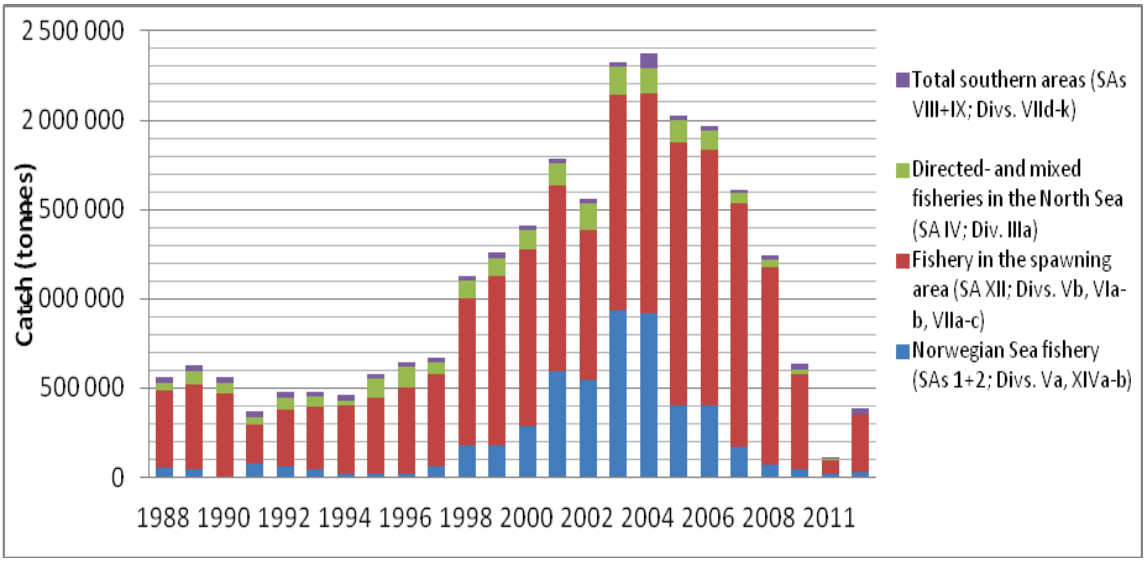


Figure 8.2.3. Blue whiting total catches (t) in 2012 by quarter and ICES rectangle. Grading of the symbols: small dots 10–100 t, white squares 100–1000 t, grey squares 1000–10 000 t, and black squares > 10 000 t. Catches below 10 t are not shown on the map. The catches on the map constitute 98% of the total catches.

A



B

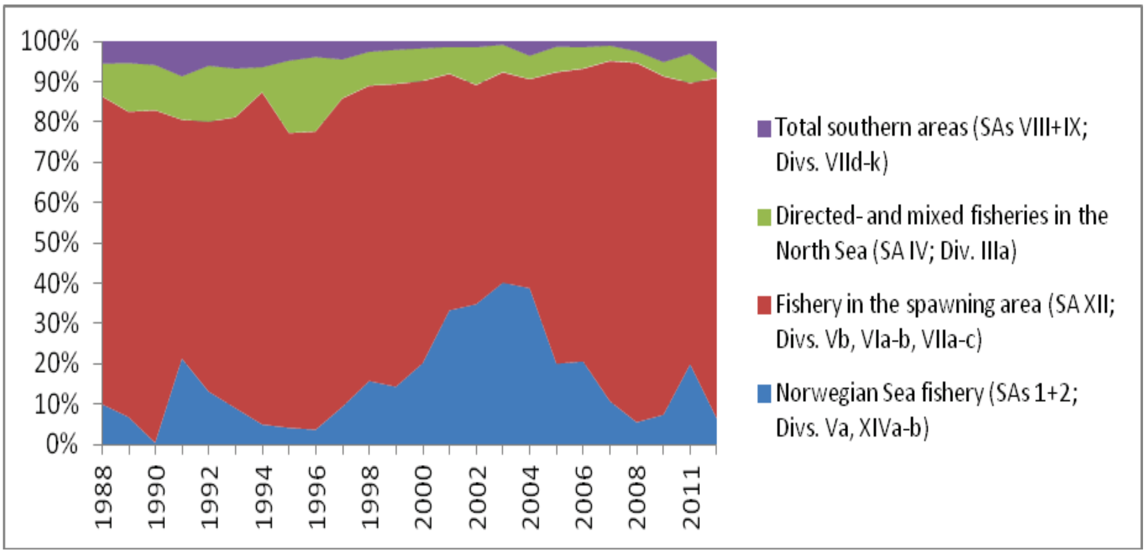


Figure 8.3.1.1. (A) Annual catch (tonnes) of blue whiting by fishery sub-areas from 1988-2012 and (B) the percentage contribution to the overall catch by fishery sub-area over the same period.

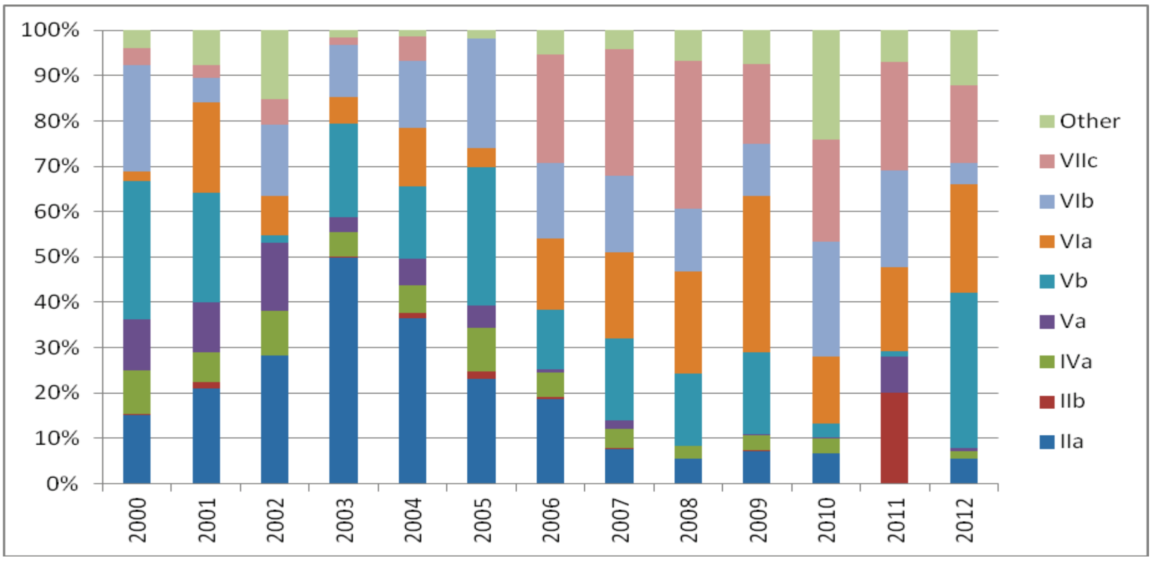


Figure 8.3.1.2. Distribution of total landings of blue whiting by ICES sub-area.

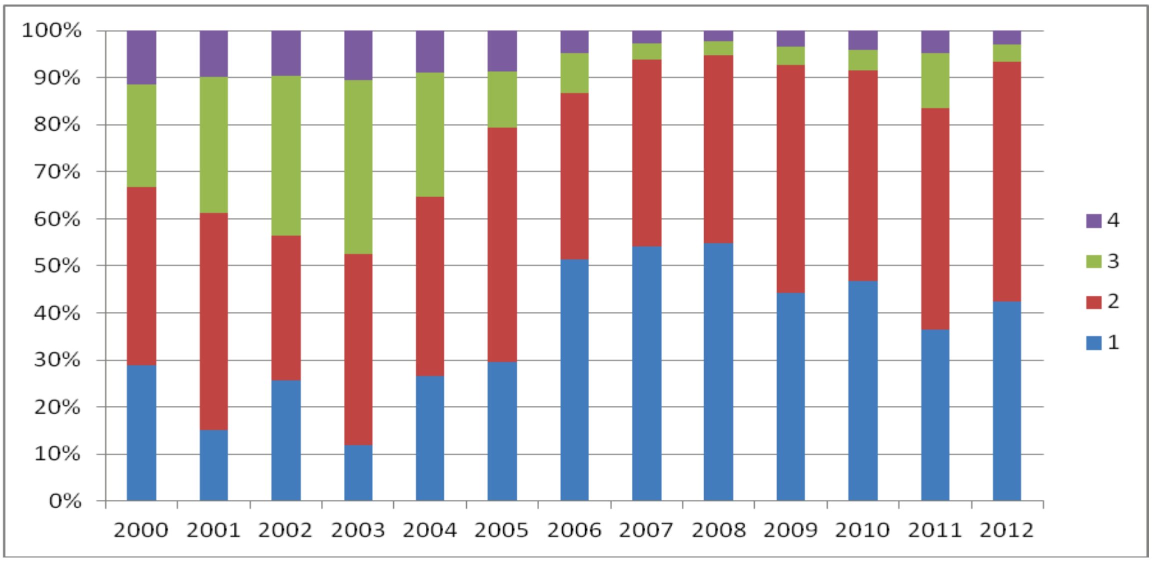


Figure 8.3.1.3. Distribution of total landings of blue whiting by quarter.

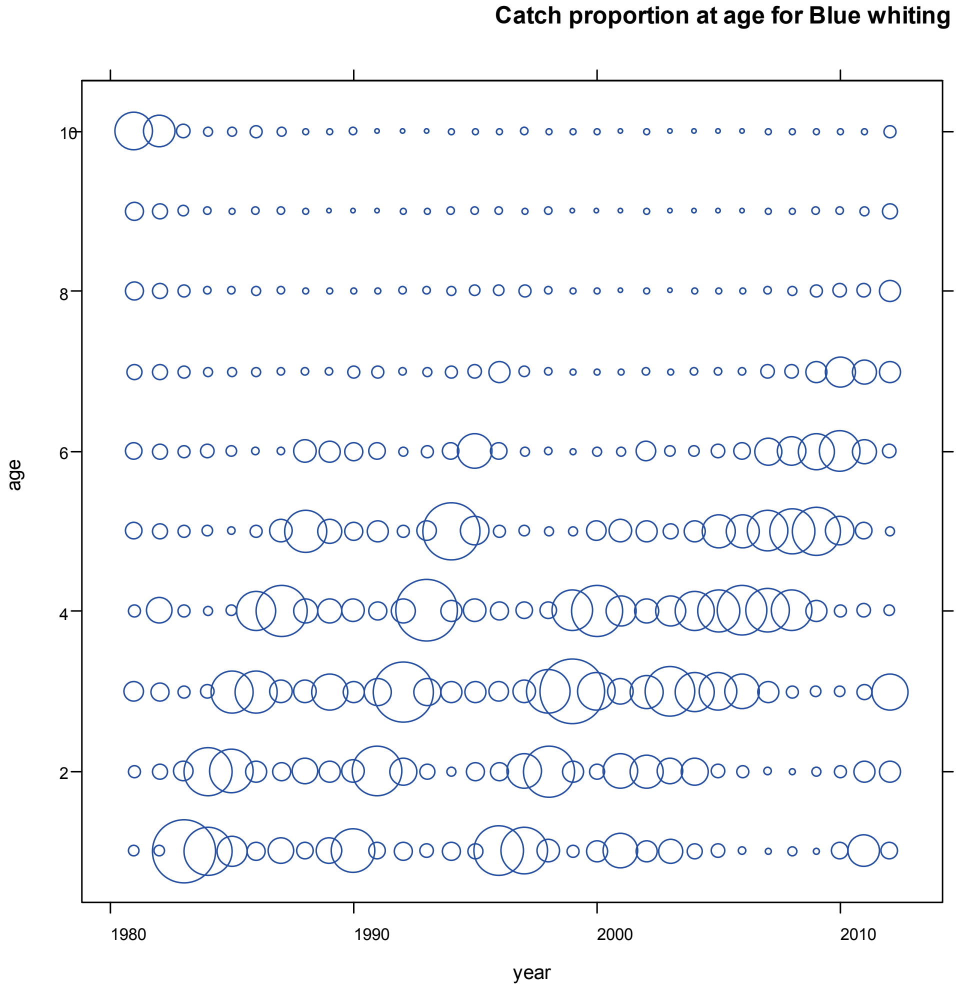


Figure 8.3.1.3.1 Catch proportion at age of blue whiting in the International catch from 1981-2012.

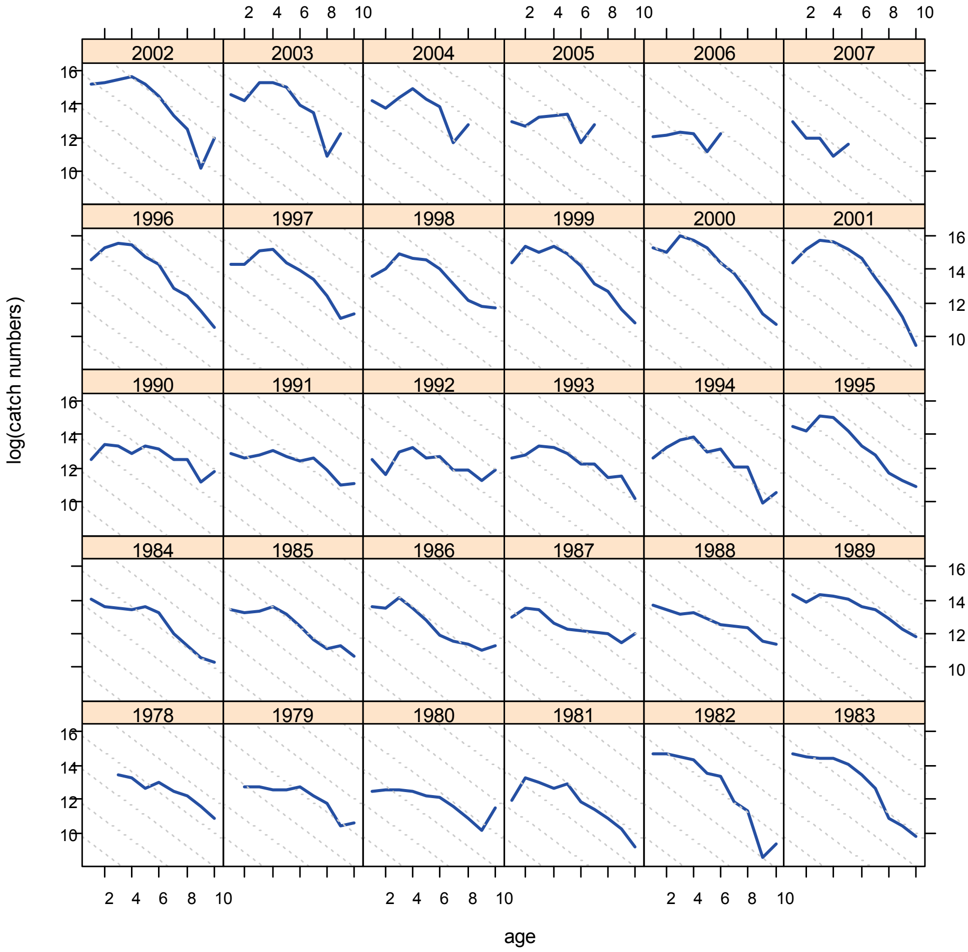


Figure 8.3.1.3.2. Blue whiting. Age disaggregated blue whiting catch (numbers) plotted on log scale. The labels behind each panel indicate year classes. The grey dotted lines correspond to *Z*=0.6.

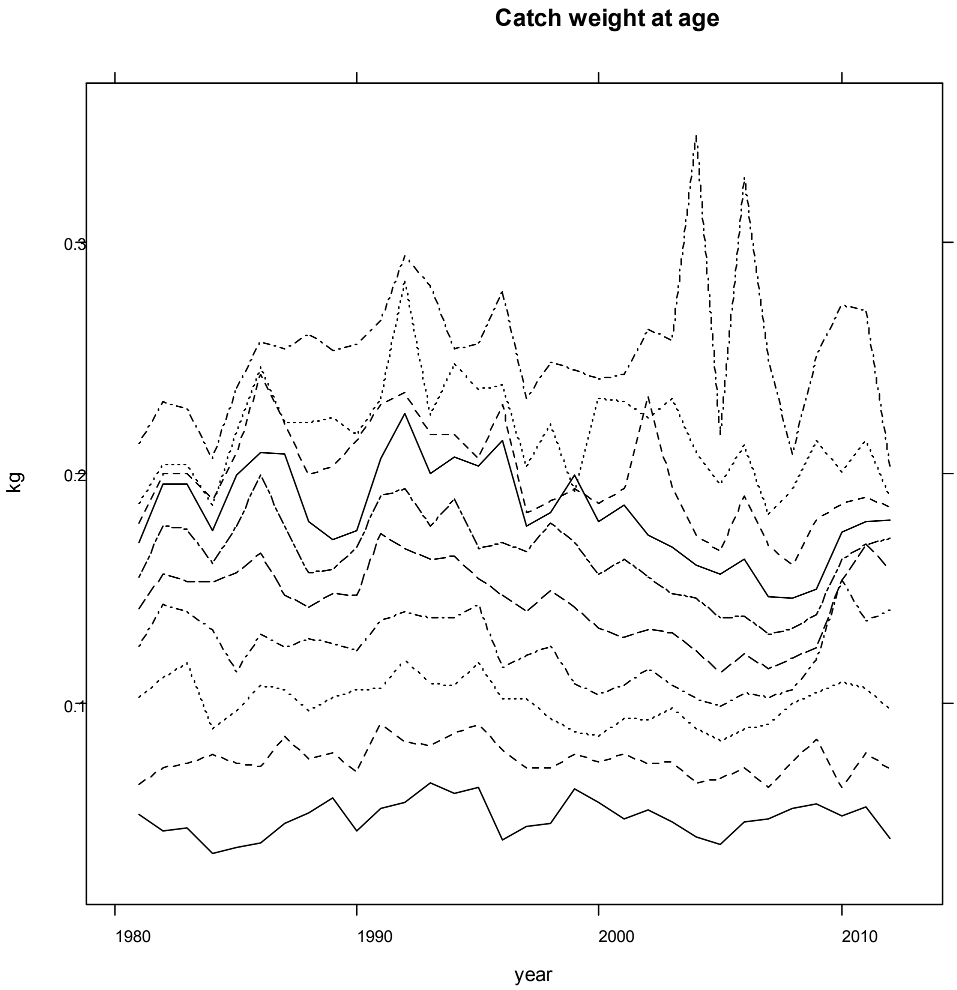


Figure 8.3.3.1. Mean catch weight (kg) at age of blue whiting by year.

A B

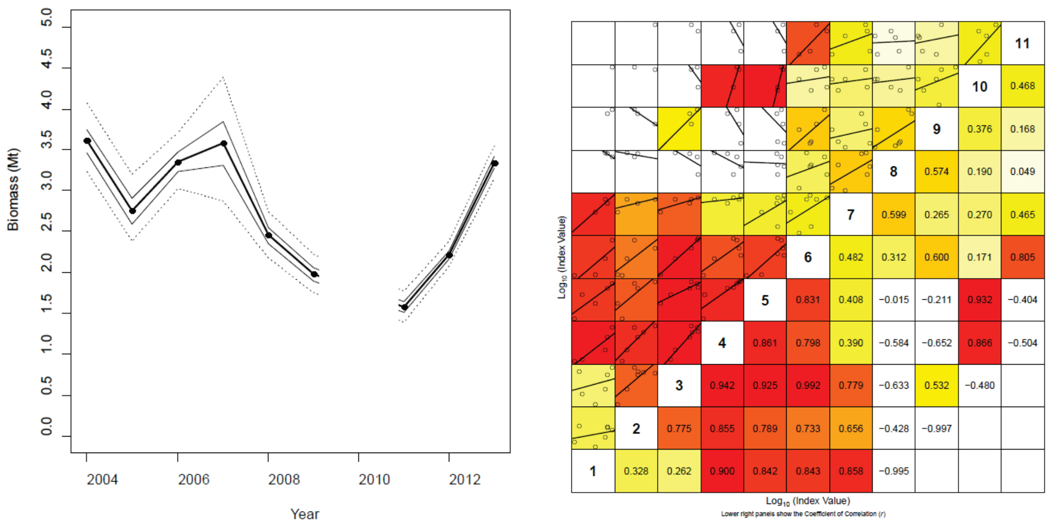


Figure 8.3.5.1.1. (A) Approximate 50% and 95% confidence limits for blue whiting biomass estimates. The confidence limits are based on the assumption that confidence limits for annual estimates of mean acoustic density can be translated to confidence limits of biomass estimates by expressing them as relative deviations from the mean values. These confidence limits only account for spatio-temporal variability in acoustic observations. (B) Internal consistency within the International blue whiting spawning stock survey. The upper left part of the plots shows the relationship between log index-at-age within a cohort. Linear regression line shows the best fit to the log-transformed indices. The lower-right part of the plots shows the correlation coefficient (r) for the two ages plotted in that panel. The background colour of each panel is determined by the r value, where red equates to r=1 and white to r<0.

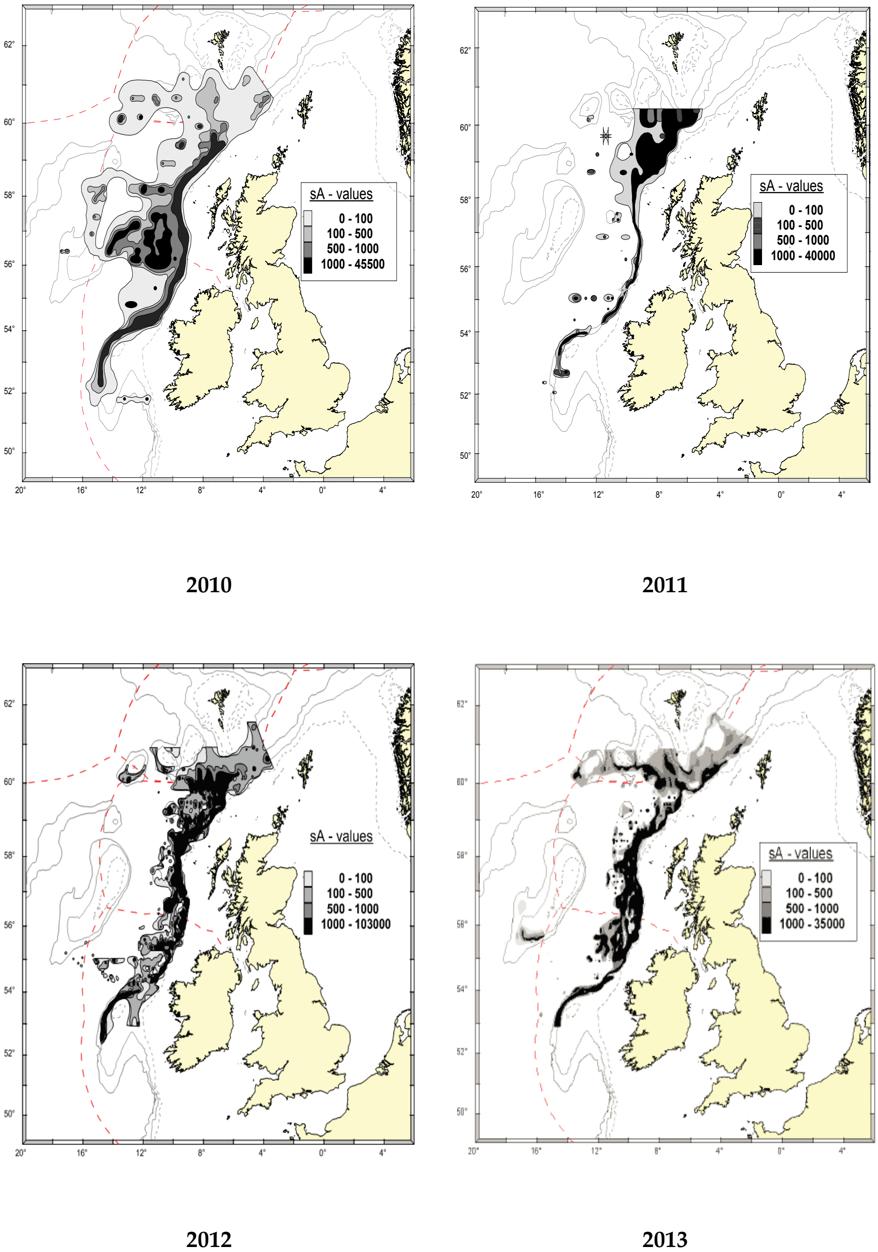


Figure 8.3.5.1.2. Schematic map of blue whiting acoustic density (sA, m2/nm2) found during the spawning survey in spring 2010-2013.

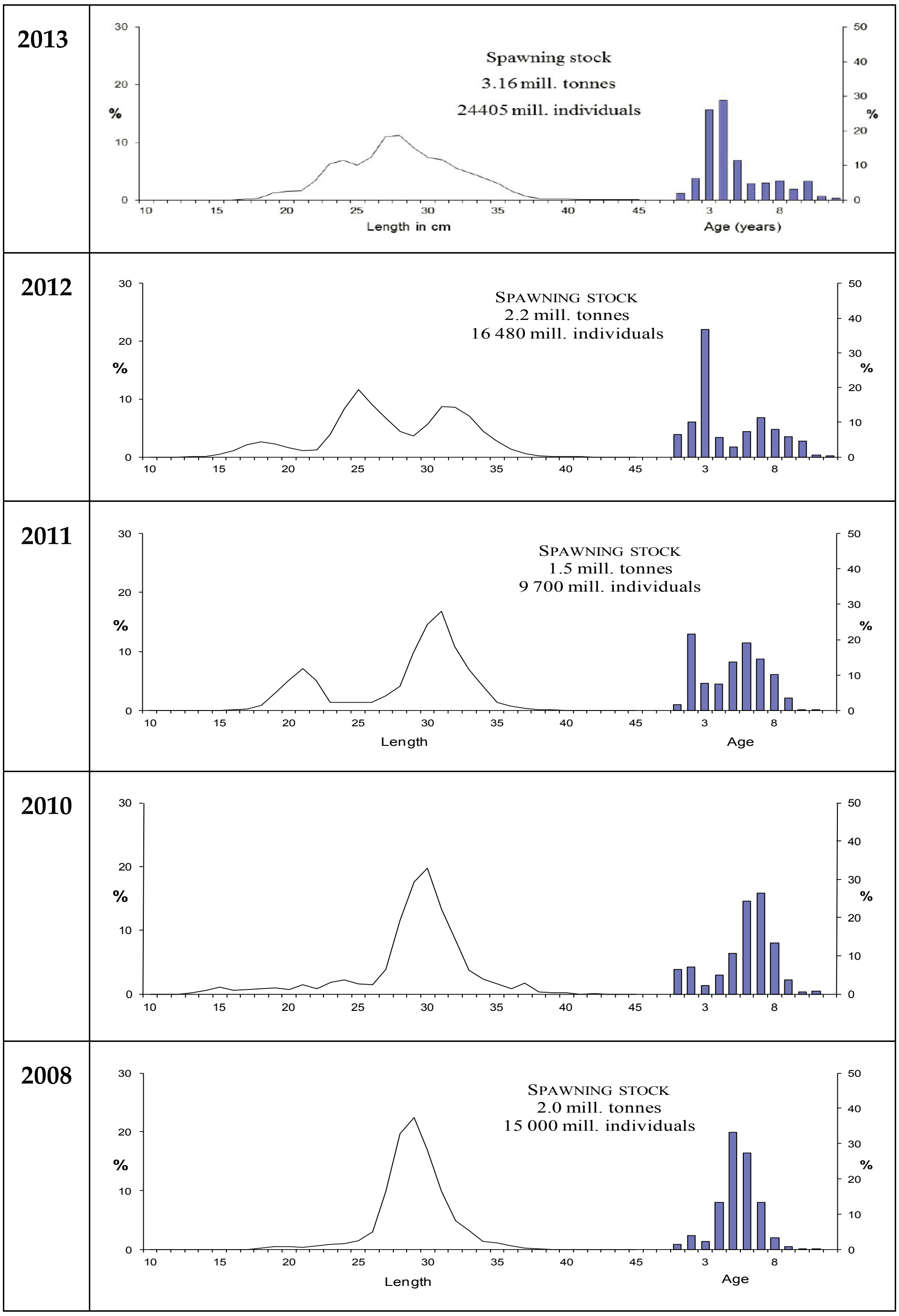


Figure 8.3.5.1.3. Length (line) and age (bars) distribution of the blue whiting stock in the area to the west of the British Isles, spring 2009 (lower panel) to 2013 (upper panel). Spawning stock biomass and numbers are given.

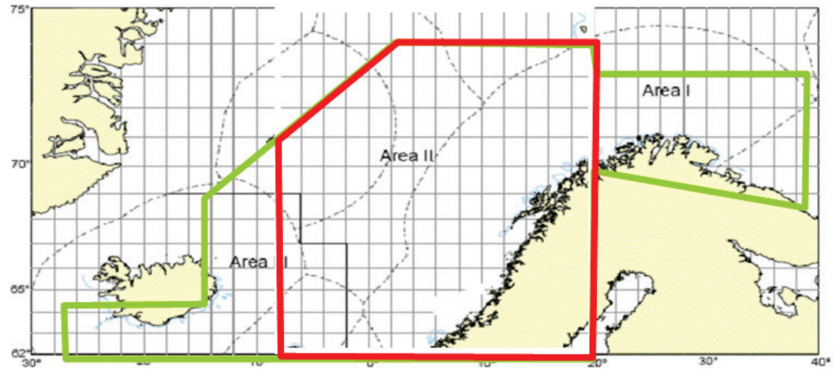


Figure 8.3.5.2.1. Areas defined for acoustic estimation of blue whiting and Norwegian spring spawning herring in the International Ecosystem survey in the Nordic Seas. The dark red box in the middle represents the standard area (8°W–20°E and north of 63°N) of which blue whiting data is used for assessment. The outer green box represents the total survey area.

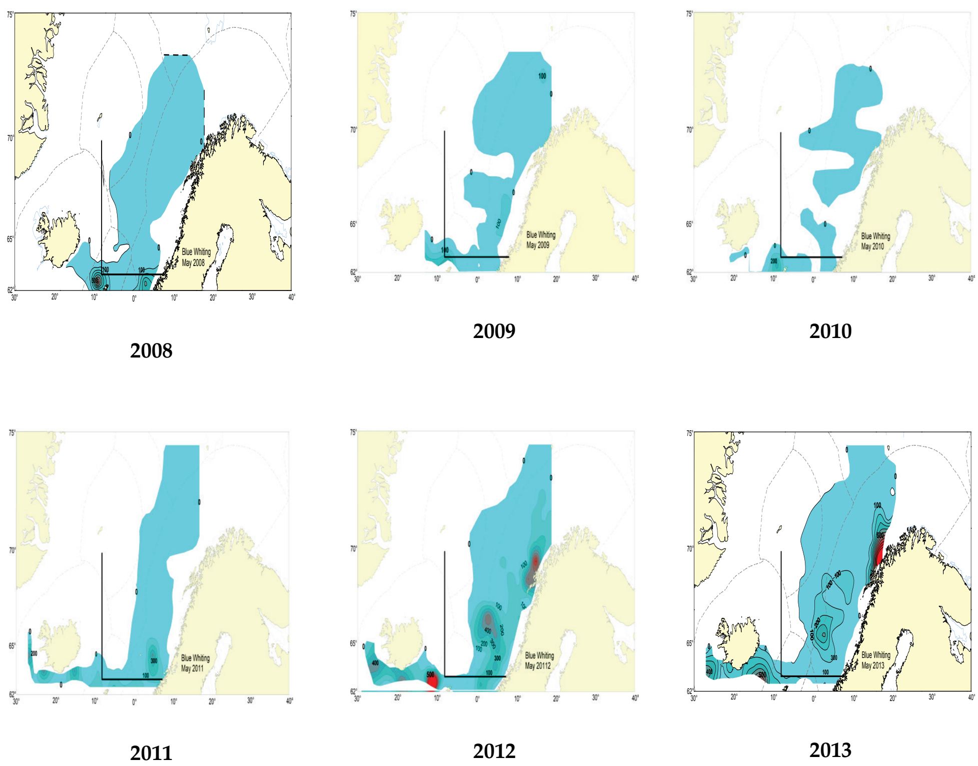


Figure 8.3.5.2.2. Schematic map of blue whiting acoustic density (sA, m2/nm2) found during the International Ecosystem survey in the Nordic Seas in spring 2008–2013.

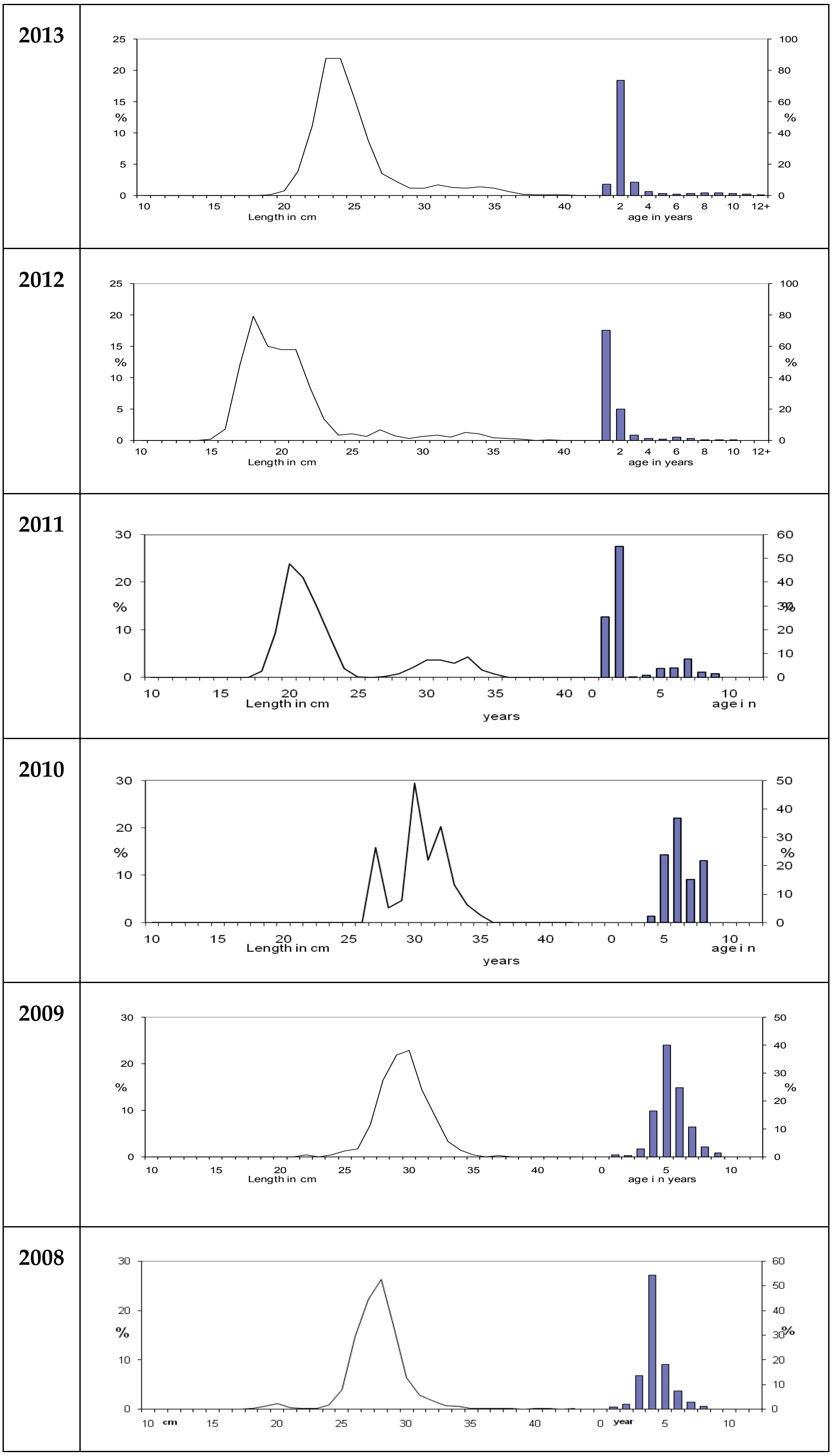


Figure 8.3.5.2.3. Estimated length (line) and age (bar) distributions of blue whiting in the International Ecosystem Survey in the Nordic Seas in May–June for 2008-2013 based on the "standard survey area" between 8°W-20°E and north of 63°N.

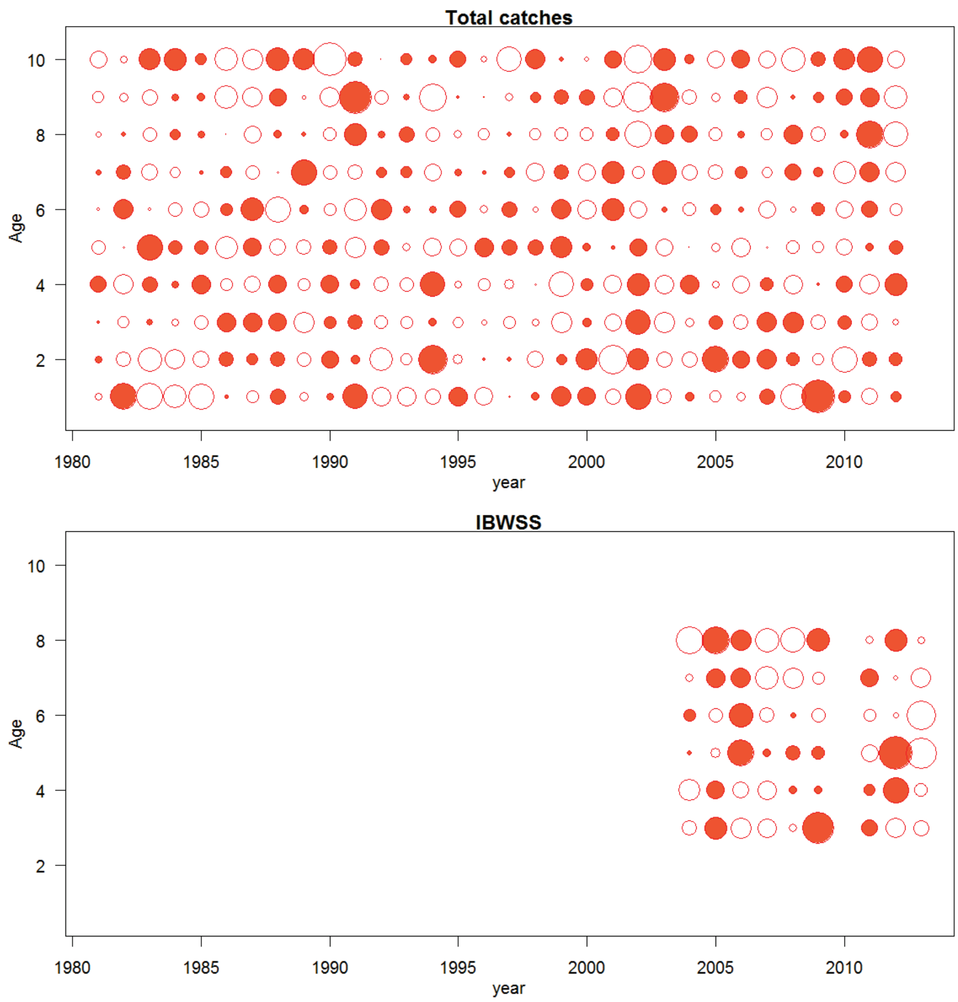


Figure 8.4.1 Blue Whiting. Standardized residuals from catch at age and the IBWSS survey. red (dark) bubbles show that the observed value is less than the expected value

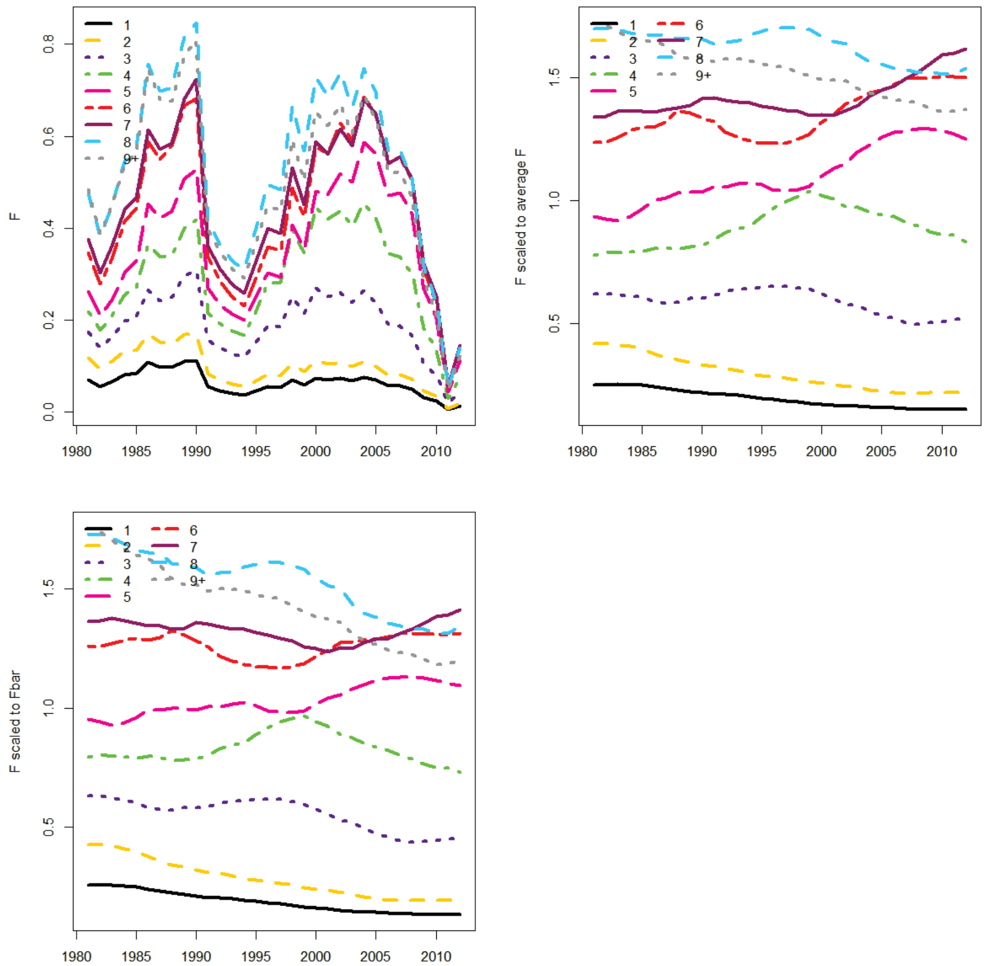


Figure 8.4.2. Blue Whiting. F at age and exploitation pattern (F scaled to mean F all ages, and F scaled to mean F ages 3-7).

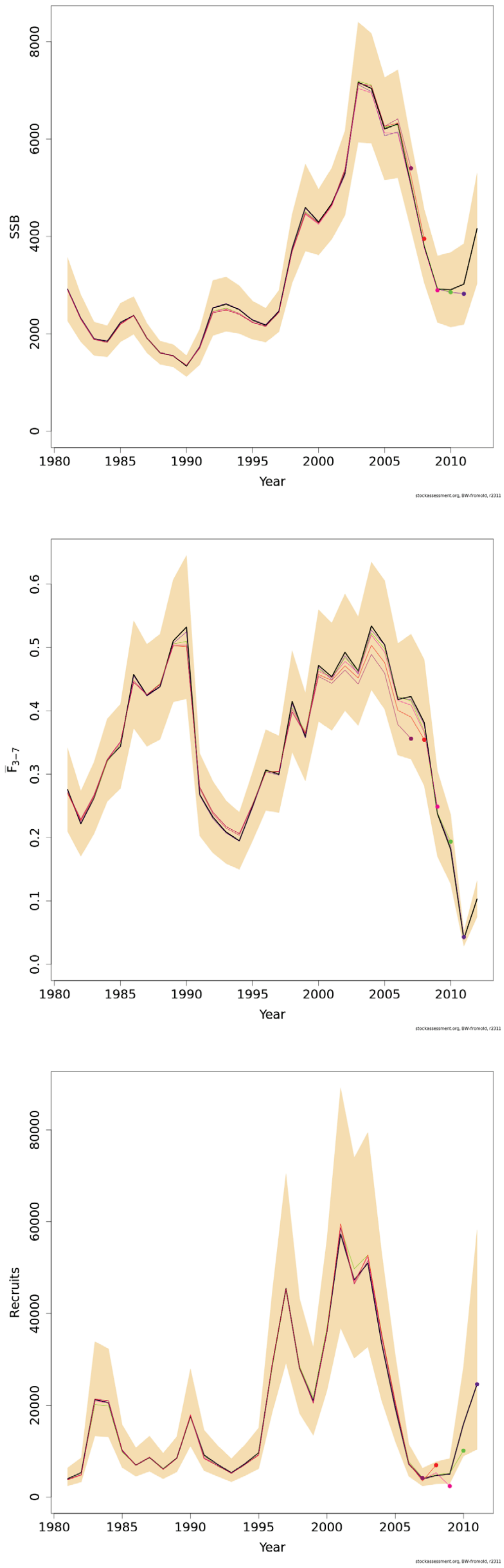


Figure 8.4.3 Blue Whiting. Retrospective analysis of SSB, F and recruitment (age 1) using the SAM model. The 95% confidence interval is shown for the most recent assessment.

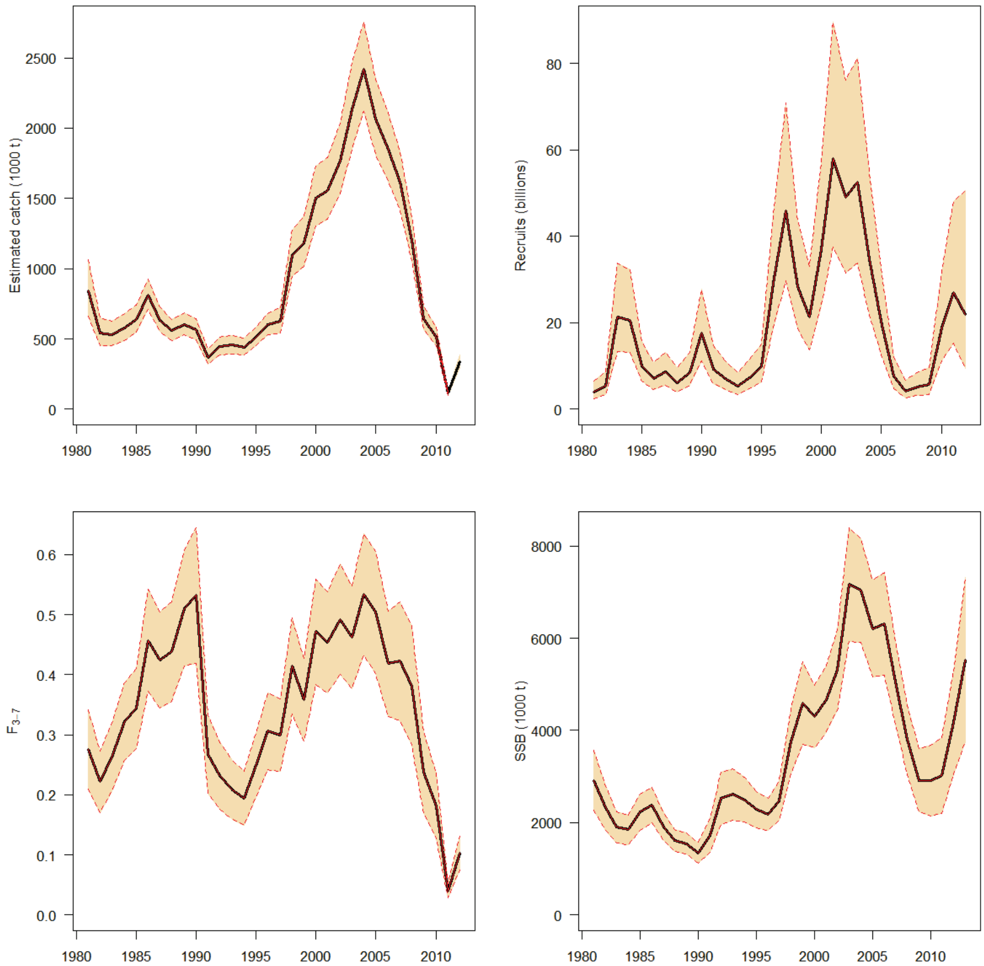


Figure 8.4.4 Blue whiting. SAM final run: Stock summary landings, recruitment (age 1), F and SSB. The graphs show the median value and the 95% confidence interval.

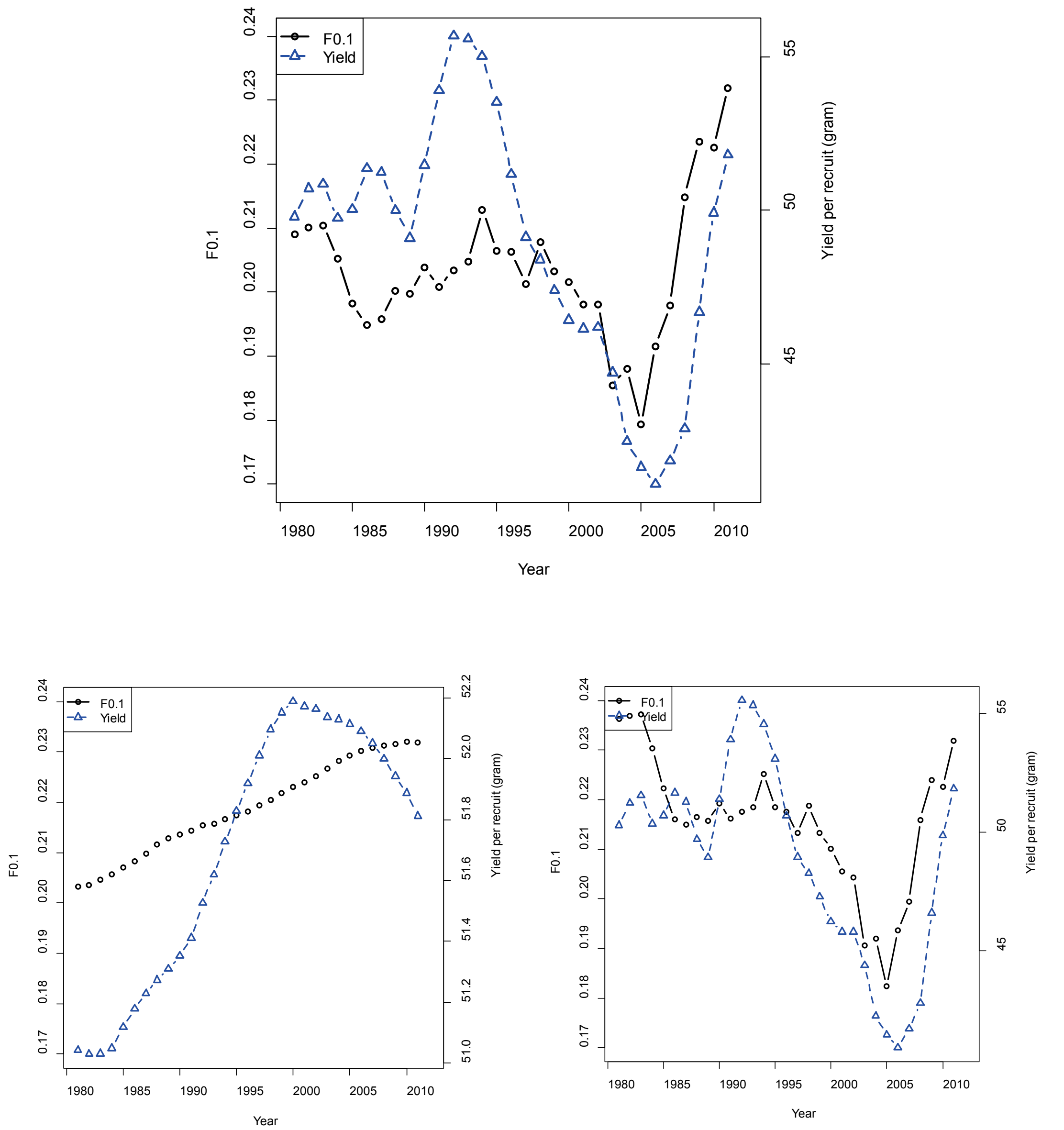


Figure 8.6.1 Estimates of F0.1 and yield per recruit by year y, using average values of exploitation pattern and mean weight at age from years: y-1, y and y+1 (Upper panel). For lower left panel the mean weight at age has been kept constant (average 2010-2012) and for the lower right panel the exploitation pattern has been kept constant (average 2010-2012).

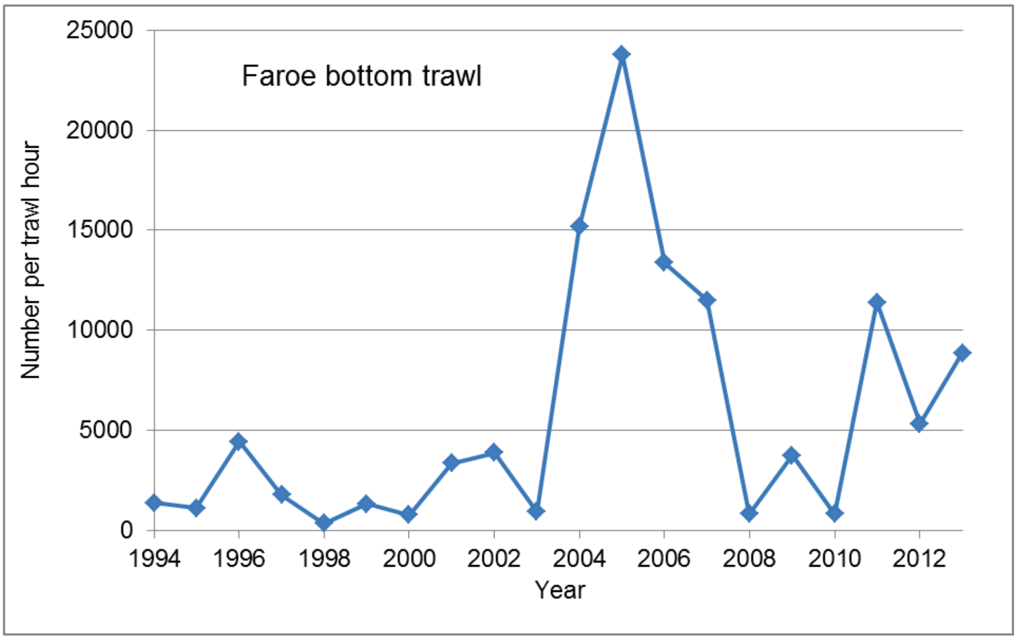


Figure 8.7.1.1. Blue whiting 1-group index (number per trawl hour) in the Faroese bottom trawl surveys in spring (March) 1994-2013. The 1-group is fish is extracted by visual inspection as fish below or equal to 22 cm.

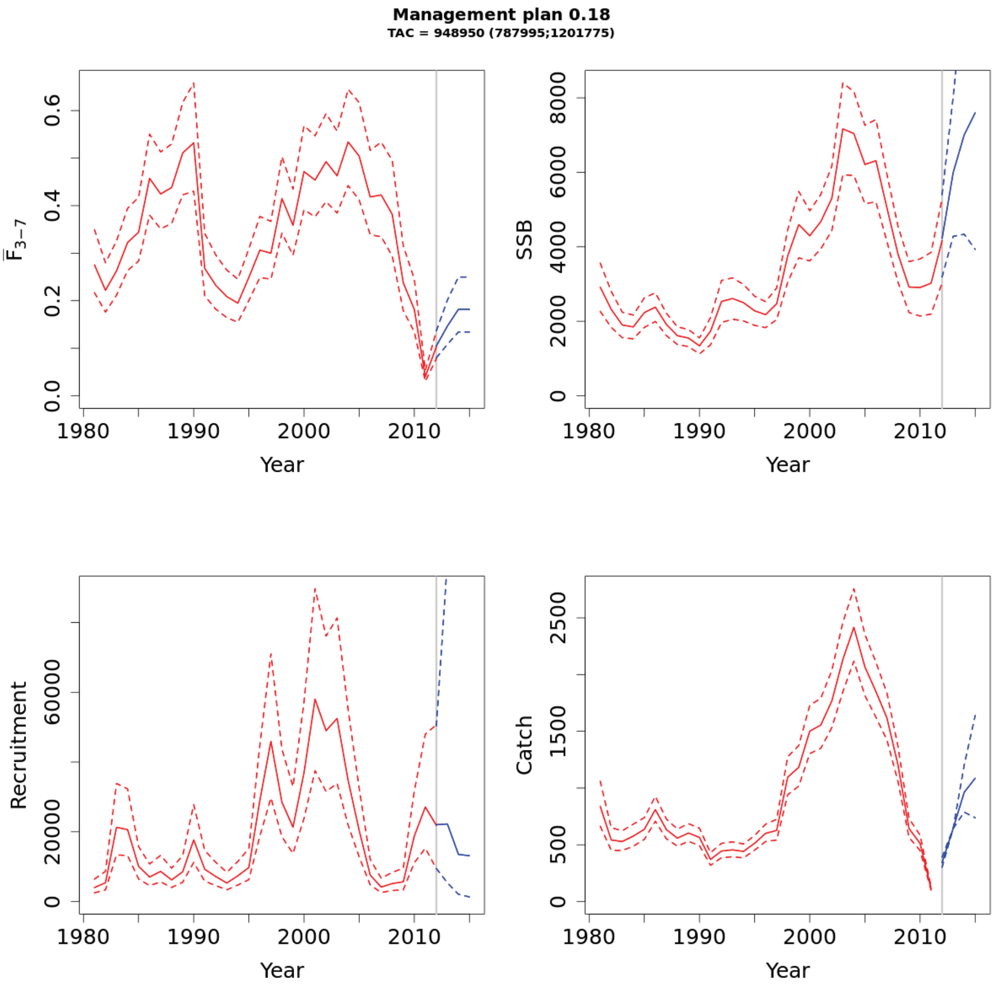


Figure 8.7.2.1 . Blue whiting. Forecast scenario for the period 2012-2015 (in blue) following the management plan. The median values and their 95% confidence interval are shown.

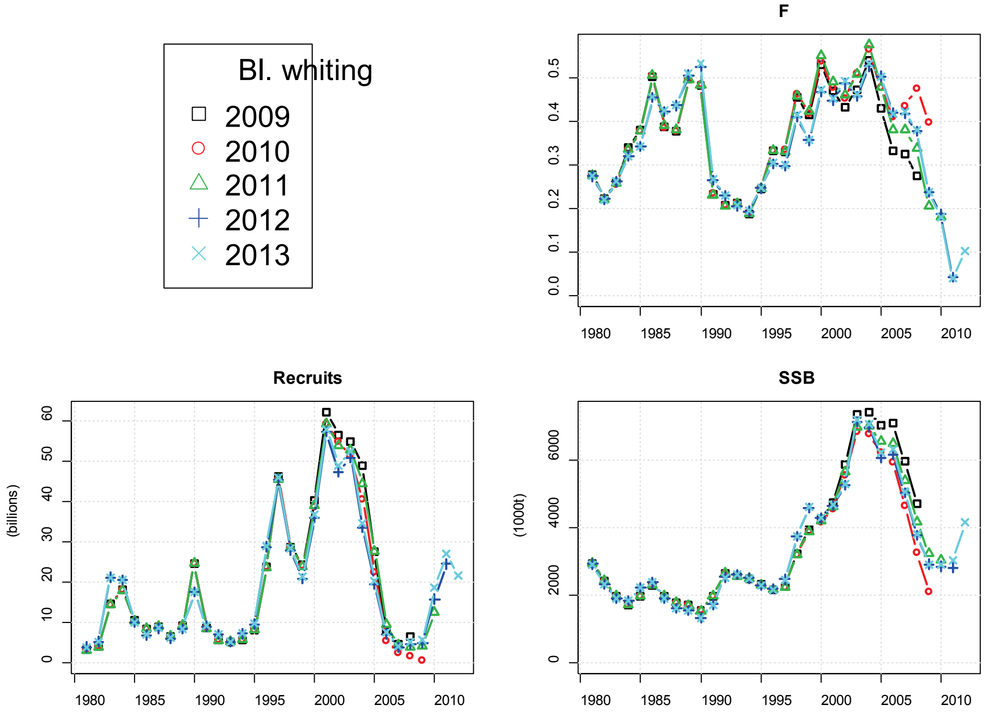


Figure 8.8.1. Blue whiting. Comparison of the 2009 - 2013 assessments.

9 Recommendations

The population structure of Blue Whiting in the North-east Atlantic appears to be more complex than the current single-stock framework used to manage it. More than a dozen scientific publications over the last three decades, based on a wide variety of techniques, have suggested the presence of many different sub-structures within the population. Precautionary management of this stock should avoid over-exploitation and depletion of any local populations, but at the same time there is no common understanding of what, if any, sub-structures exist in the population or their relative size. WGWIDE therefore proposes, in conjunction with the Stock Identification Methods Working Group (SIMWG), the creation of a study group to:

a) Collate and review all published work on the potential population structure of Blue Whiting the North-east Atlantic

b) Identify, collate and analyse alternative data sources that could shed further light on the population structure

c) Synthesise these results into a unified conceptual model of Blue Whiting population structure and

d) Advise on the biological appropriateness of the current management structure

10 Working Documents

The Working documents are listed below in the pdf version of the Report.

Mackerel swept area abundance by age from the July surveys (IESSNS) – first attempt

Sigurður Th. Jónsson, Leif Nøttestad, Guðmundur Oskarsson and Jan Arge Jacobsen

The development of the IESSNS continues, and all parties are striving for standardisation, and the 2013 survey was considered the most reliable in terms of survey gear standardisation as well as the trawling procedures among the vessels.

An annual, standardised, quantitative survey could be helpful in the assessment of the NEA–mackerel stock. The following is a first attempt, albeit rudimentary, at using the data from the July surveys to establish an age disaggregated index, with the potential to be used as a tuning series in the assessment. This draft is a first attempt towards that goal.

An overview of the biological sampling and a few biological parameters of the samples are shown by year (2010-2013) in Table 1. The distribution of the individual biomass indices by station each year is fairly similar (Fig. 1), indicating a rather homogenous distribution of mackerel during summer.

The age disaggregated indices from the catches were converted from biomass to abundance, based on the average weights measured. If a station was lacking observations of weight or age (lengths was measured in almost 100% of cases), the closest station in the same rectangle was used. However if weights or ages of individual fish were missing from a rectangle, it was left out in the present analysis -this will be addressed in further work. Note that the majority of rectangles included in the estimate had stations with biological data included.

Only the swept area biomass indices (kg/km^2) were carried from the stations to rectangles as averages. Disaggregation was performed on the basis of available length measurements within rectangles. We did not do any weighing of length or weight distributions within the squares. However, the material is fairly homogeneous in terms of measurements, so in case of multiple stations, the observations were pooled without weighting.

For now, we didn’t attempt an estimate based on an age–length keys, next step would be applying a preliminary overall key for each year. Finalising would include length-stratified keys, as there is a clear size gradient with increasing the size towards west.

As this is a first quick attempt, the results are not doubled checked and the total disaggregated indices weren’t available, only the percentage age distributions by year. Nevertheless, the consistency in the results seems to be reasonable by inspections from Fig. 2, where it is possible to follow "strong" year-classes from year to year.

Table 1. Summary of biological sampling on the IESSNS surveys.

Parameter	2010	2011	2012	2013
N measured	14215	9496	18938	25374
B measured (g)	5490487	2790217	5412505	6221120
% length measured	100%	100%	100%	100%
% weighed	100%	74%	79%	78%
% aged	15%	16%	21%	20%
% maturity staged	45%	38%	30%	30%
Mean length (cm)	34.5	34.3	34.1	33
Mean weight (g)	386	395	360	316
Mean age (years)	4.5	5.5	5.5	5.1
% mature	100%	99%	97%	94%
a	0.0118	0.0029	0.0173	0.0077
b	2.93	3.33	3.06	3.04

Where *a* and *b* are the coefficients from a simple log–log fit of weight on length on all observations within a year (with minor filtering of erroneous measurements). These relationships were used for predicting weight for all fish.

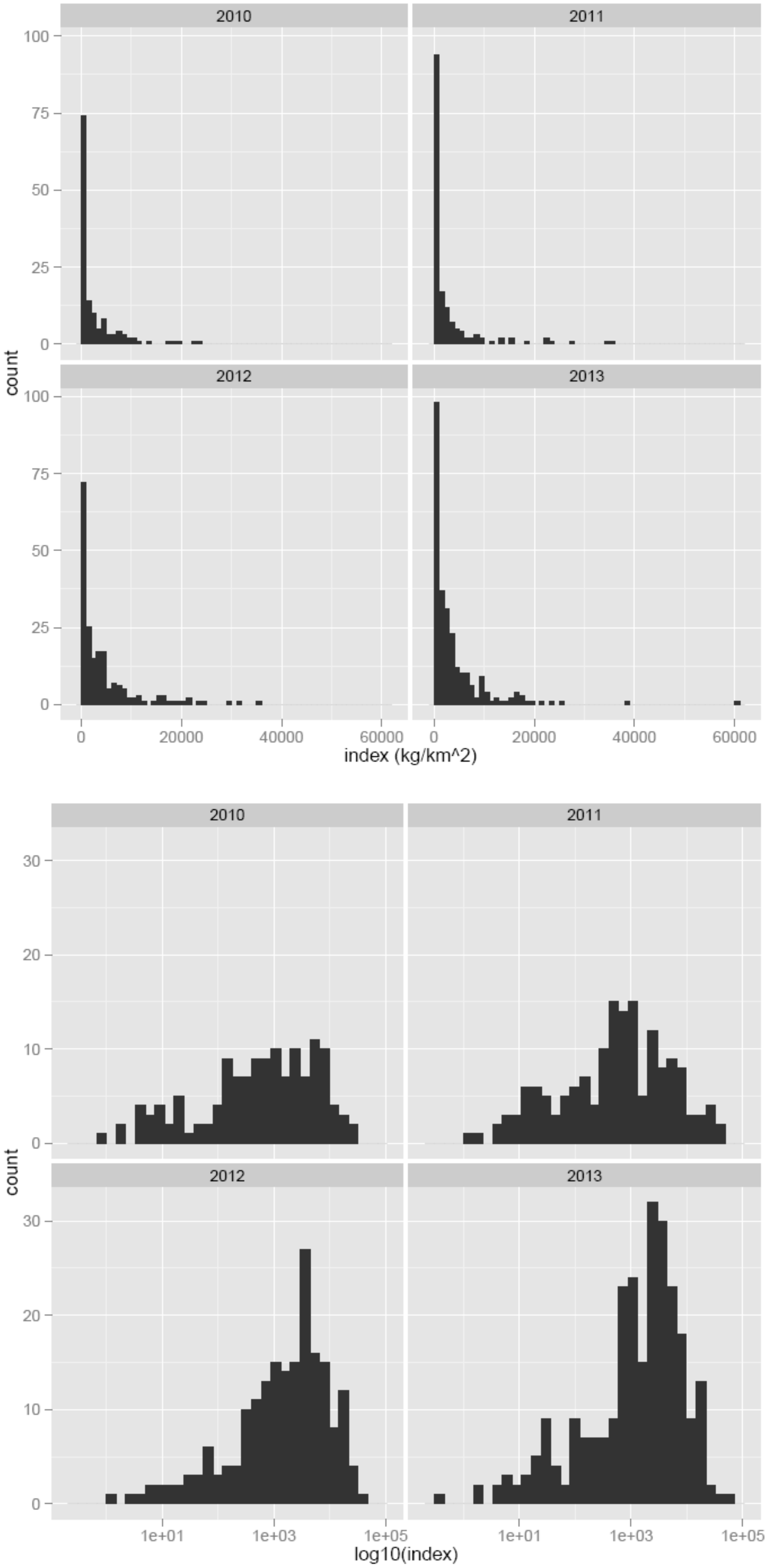


Figure 1. Distribution of swept area biomass indices from all stations by year: (upper panel) as observed/calculated, and (lover panel) as log–transformed values.

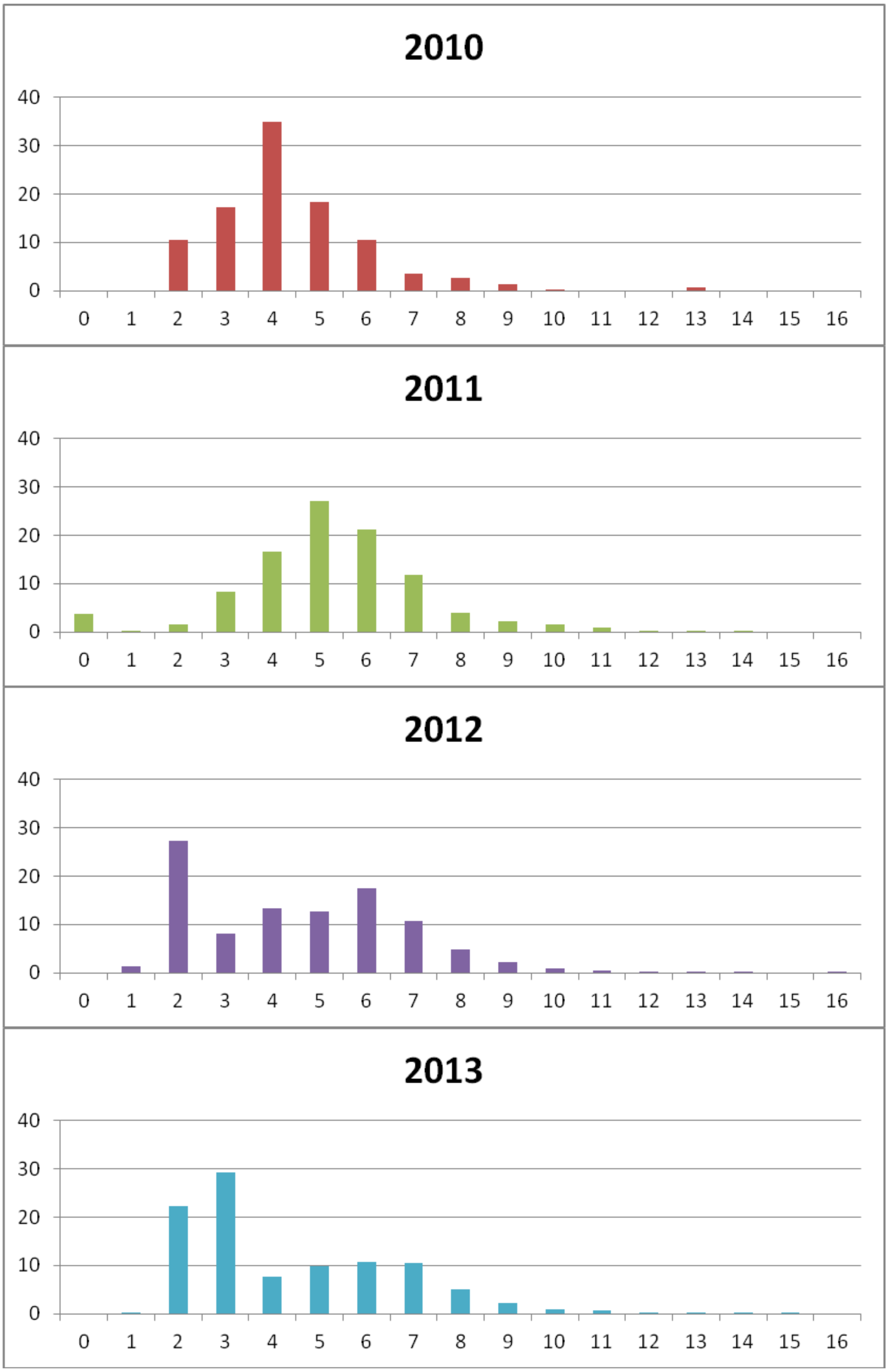


Figure 2. Age distributions (%) of mackerel from the July surveys 2010-2013 (IESSNS).

Estimates of discarded boarfish by Dutch pelagic freezer trawler fishery in 2003-2012

Harriët M.J. van Overzee and Aloysius T.M. van Helmond
IMARES, Wageningen UR

From 2002 onwards discarding by Dutch commercial pelagic trawlers fishing in European waters is monitored under the European Data Collection Framework (DCF). The Dutch fleet of freezer trawlers use a mid-water pelagic trawl to target pelagic species. Their most important fishing grounds in European waters are situated on the continental slope west of the British Isles, in the English Channel, along the British eastern coast, the northern North Sea and the Norwegian Sea (Figure 1).

The Dutch pelagic discard sampling programme aims at sampling twelve trips per year, corresponding with a sampling coverage of around 10% (in number of trips). Discard estimates for boarfish have been derived from the sampling programme. Total discard weight per species and trip has been raised to fleet level by total number of trips per quarter per year (Table 1). When a species is not caught during a sampled trip, it has been marked zero (Van Helmond & Van Overzee 2009; 2010; Van Overzee & Van Helmond, 2012). The raised boarfish discards, solely based on sampled information, are presented in Table 1.

The data collected by the scientific observers show that occasionally part of or the whole catch is discarded without sorting; relatively large amounts of catch are released via the conveyer belt from the cooling tanks or directly from the net. We refer to this type of discarding as "unsampled discards[1]". As it is impossible for the observers to biologically sample discard events, accurate numbers per species cannot be calculated. It is therefore decided to not include these events in the raised species specific discards. While we recognize that by not including them this results in an underestimation of the boarfish discards, we believe that leaving out this correction is decreasing the noise in the data, and therefore a more desirable approach in estimating species specific discards.

[1] This type of discarding is internationally often described as slippage (Borges *et al.*, 2008). However, we believe that this term does not sufficiently describe this process as the terminology suggest that catch is only directly discarded from the net.

Table 1: Overview of the fleet activity, number of trips observed and raised boarfish discards (in tonnes) in the Dutch pelagic freezer trawler fleet per year (2003-2012).

	Number trips pelagic Dutch flagged fleet	Number sampled trips	Boarfish discards (tonnes)
2003	131	5	1998
2004	131	6	837
2005	142	12	733
2006	122	12	411
2007	124	12	23
2008	110	12	738
2009	93	11[ab]	1258
2010	91	8[cb]	512
2011	88[#]	15[db]	185[*]
2012	85	12[eb]	88

[a] This includes 9 trips on board Dutch flagged vessels, 1 trip on board a German flagged vessel and 1 trip on board a British flagged vessel

[b] As it can be assumed that the foreign flagged vessels exhibit the same fishing behaviour as Dutch flagged vessels, trips on board foreign vessels were treated as if they belonged to the Dutch fleet

[c] This includes 5 trips on board Dutch flagged vessels, 1 trip on board a German flagged vessels and 2 trips on board British flagged vessels

[d] This includes 14 trips on board Dutch flagged vessels and 1 trip on board a French flagged vessel.

[e] This includes 8 trips on board Dutch flagged vessels, 2 trips on board a French flagged vessels and 2 trips on board German flagged vessels

[#] Number of trips have been adjusted

[*] Adjusted according to most recent information (see comment above)

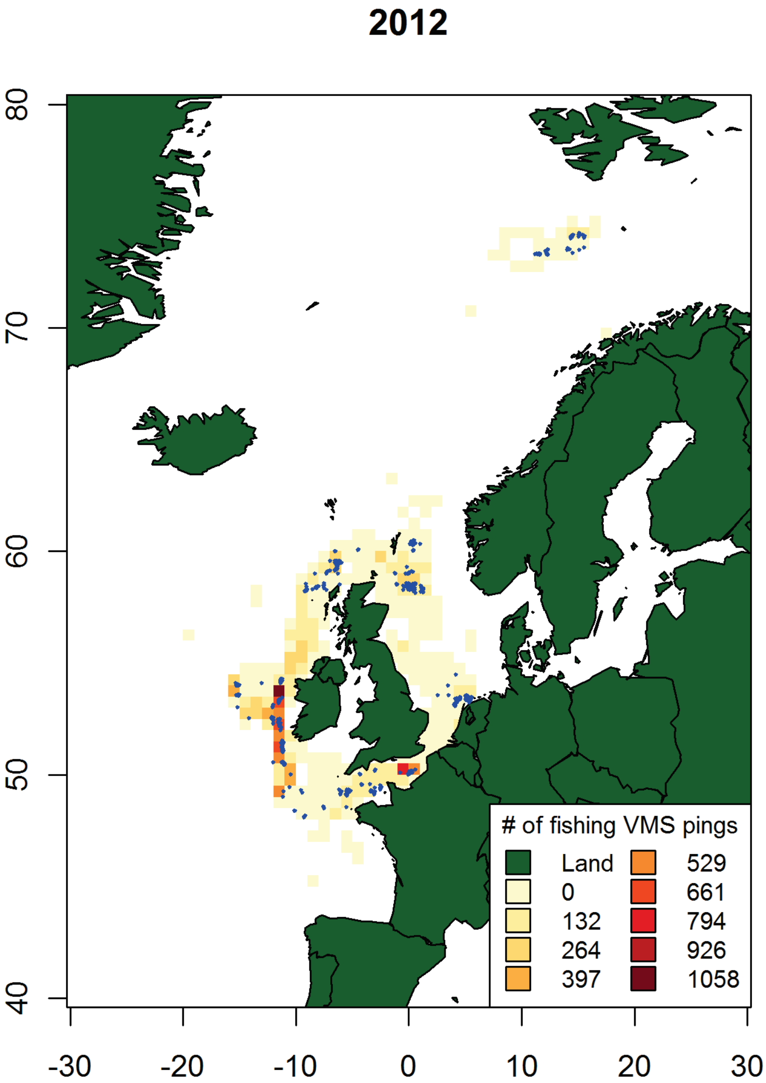


Figure 1: Distribution of the Dutch pelagic fleet (based on VMS data) and positions of **all** sampled pelagic discard trips per haul for 2012 (blue points).

References

Borges, Lisa, Olvin A. van Keeken, Aloysius T.M. van Helmond, Bram Couperus and Mark Dickey-Collas (2008). What do pelagic freezer-trawlers discard? ICES Journal of Marine Science, 65: 605-611.

Helmond, A.T.M. van & H.M.J. van Overzee (2009). Discard sampling of the Dutch pelagic freezer fishery in 2003-2007. CVO Report 09.001, 60 pp.

Helmond, A.T.M. van & H.M.J. van Overzee (2010). Discard sampling of the Dutch pelagic freezer fishery in 2008-2009. CVO Report 10.008, 63 pp.

Overzee, H.M.J. van & A.T.M. van Helmond (2011). Discard sampling of the Dutch pelagic freezer fishery in 2010. CVO Report 11.010, 49 pp.

Revising the maturity ogive for blue whiting

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Introduction

This document presents a first attempt to revise the maturity ogive for blue whiting, hopefully paving the way to inter-sessional work to revise the ogive for WGWIDE 2014. The current maturity ogive for blue whiting originates from 1994. The stock annex states the following:

> "Maturity at age used in the assessment was obtained by combining maturity ogives from the southern and northern areas, weighted by catch in numbers at age (ICES, 1995). These values have been used since 1994. Although the values of maturity at age may be too low, sufficient information for estimating new ogives is not available." (ICES 2012, p. 842)

This leaves open when and how the ogives for the southern and northern areas were derived in the first place, so it is rather difficult to make any judgements regarding how good (or bad) the ogives were 20 years ago or are now[1].

Errors in maturity-at-age are directly reflected in estimates of spawning stock biomass based on stock numbers and weight, and thereby it is important to try to understand how much bias and error may be entering the SSB estimate this way.

When the ogive for the northern stock component was estimated, there were two surveys covering larger parts of the stock: the Norwegian and Russian spawning stock surveys (March–April), and the Norwegian pelagic survey in the Norwegian Sea in July–August. The first survey represents almost only spawning fish, whereas the latter survey represents both immature and mature fish. Because the surveys are far apart in time, mature fish have ample time to move from one survey area to another, and the "same" fish could be observed in both surveys. One does not want to count the same fish twice, so it was difficult to combine data from these surveys.

However, the situation has changed. The spawning stock survey has developed into an international, coordinated survey (starting 2004). The survey in the Norwegian Sea in July–August became supplemented by another survey conducted in late spring, gradually becoming a coordinated survey with broad international participation (from about 1997, and further improving over time) and eventually replacing the old survey in July–August (discontinued in 2001). Thus, since about 2004, there has been coordinated, international survey coverage of the stock at both the spawning and feeding areas. The surveys are now only 1–2 months apart, reducing (but not totally eradicating) the problem of counting the same fish twice. This gives a much better basis for estimating maturity-at-age by combining survey data from spawning and feeding areas.

Methods

Data from 2004 to 2012 corresponding to the spawning stock survey in March–April and the pelagic ecosystem survey in May–June were extracted from the database of the Institute of Marine Research.

[1] I do not have the reports, but I seem to remember that the northern ogive was derived in early 1980's.

Thus only data collected by Norwegian vessels (either research vessels or chartered fishing vessels) were used. Estimated numbers-at-age corresponding to the aforementioned surveys were extracted from the 2012 assessment report (ICES 2012, Tables 8.3.5.1.1 and 8.3.5.2.1). Numbers-at-age for the pelagic ecosystem survey before 2012 were divided by 3.1 to account for the change in the target strength (Pedersen et al. 2011). A weighting factor for each individual observation was calculated as $w_{a,y,s} = N_{a,y,s}^{estimated} / N_{a,y,s}^{sampled}$ where the numerator is numbers per age per year per survey in the acoustic survey estimate and denominator is the total sampled numbers per age per year per survey. Individuals in macroscopic maturity stage 1 ("immature", coded as 0) were considered immature and all above (stages 2–7, coded as 1) mature (cf. Mjanger et al. 2010). Maturity-at-age can then be calculated as a mean maturity-at-age, weighted by the factor defined above.

Results

The ogive derived using the Norwegian survey data combined with estimated numbers-at-age suggests that the current ogive underestimates maturity by about 10–20 per cent points in age groups 2 to 7 years (Figure 1, Table 1). Recalculating SSB using the estimated stock numbers-at-age and weights-at-age from the 2012 assessment shows, as expected, that SSB is revised upwards. Looking at the absolute estimates gives an impression that the revision amounts to a mere re-scaling. However, a closer look on the results shows that the upward revision has fluctuated between 5% and 21% (assuming that the new ogive is representative for the early years, which can of course be questioned). The bias is largest when the spawning stock is dominated by young fish.

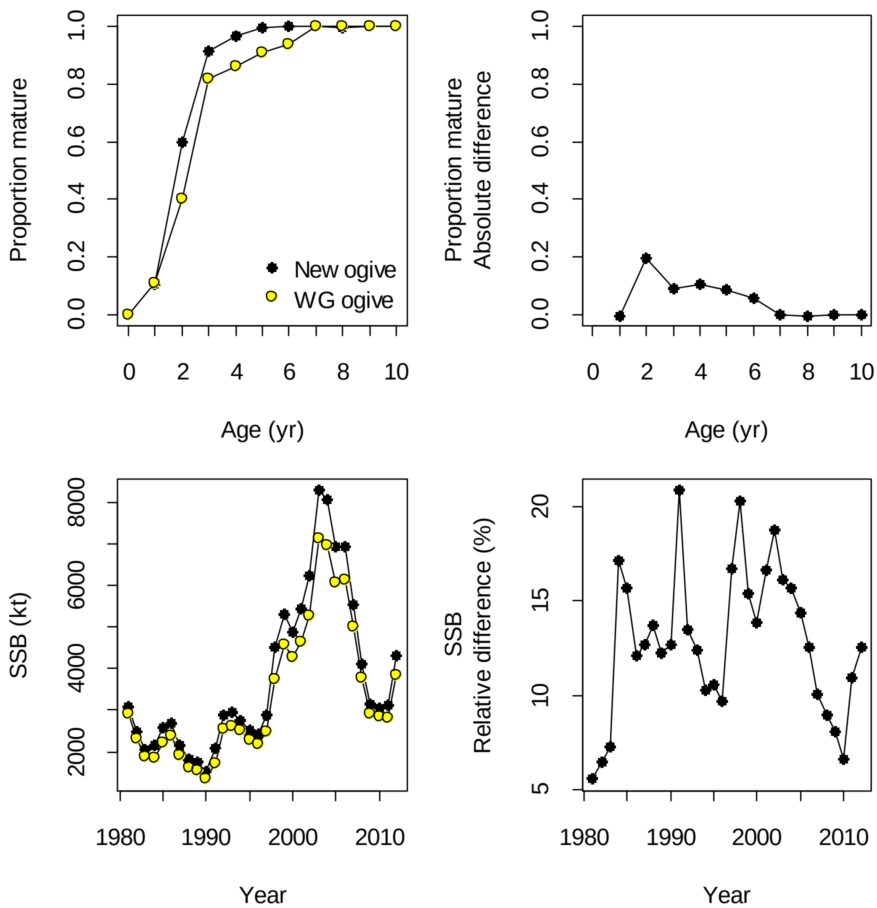

Figure 1. The provisional revised maturity ogive and its consequence for SSB.

Table 1. The current maturity ogive used in WGWIDE and the provisional revised maturity ogive.

Age	0	1	2	3	4	5	6	7	8	9	10
WG ogive	0	0.11	0.40	0.82	0.86	0.91	0.94	1.00	1.00	1.00	1.00
New ogive	0	0.10	0.60	0.91	0.97	1.00	1.00	1.00	1.00	1.00	1.00

Concluding remarks

Some of the hidden assumptions above are:

- Both surveys have the same relative observability. This is not true (if not for any other reason) because the estimate in Table 8.3.5.2.1 is for the “standard survey area”, so numbers-at-age are underestimated. This probably leads to overestimation of maturity-at-age.
- The same fish are not observed twice. This is probably not true either because some spawning fish will have moved to the area surveyed in May by that time. This probably leads to overestimation of maturity-at-age.
- Years receive relative weight that is proportional to stock numbers. Giving equal weight to each years is easily done but unlikely to have much effect.
- Norwegian data are representative. Hard to judge but easy to test.

The considerations above suggest that the provisional ogive represents the worst case—that the “true” ogive might lie somewhere between the old and new ogive.

The results here suggest that there is a significant downward bias in current SSB estimates. Assessments are relatively immune to a constant bias, but because the maturity ogive seems to be most biased for age 2 years, there is an error that varies from year to year, as long as incoming year classes differ in strength. I recommend estimating a new maturity ogive using all available data (i.e., also other countries than Norway), with appropriate checks for sensitivity of the estimate to data sources and structural assumptions.

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Working Document to WGWIDE 2013
ICES 26/8-2/8 2013

Multpelt 832 trawl monitoring during mackerel swept area survey

Jan Arge Jacobsen & Anna Ólafsdóttir

Trawl gear monitoring during the international mackerel swept area trawl survey in July 2013 (ISSENS).

Four set of sensors were attached to the Multpelt 832 trawl used on board the Faroese Finnur Fríði to monitor the trawl gear performance during the mackerel trawl survey. The sensor arrangement and placement is shown in Figs 1-3. The sensors were monitored continuously during each haul for the whole survey (37 trawl stations). The four set of sensors measured the door spread (L), spread of the underwings (V), width of the trawl opening (side-net, S), and depth of the groundrope (G). The width of the trawl opening and spread of the underwing was not always possible to record due to either poor connection up to the vessel or twisted position of the sensors during the shooting process of the trawl. The sensors attached to the underwing were placed inside protective cases (Fig. 4) to ensure that they were faced towards at each other during towing. They were placed immediately in front of the tip of the underwing on the extension chain.

The average measurements of the various parameters are shown in Table 1 along with standard deviations and number of measurements. The towing speed is also shown. The measurements of the four parameters (L, V, S, and G) are shown in Figs 5-8. Some variability can was observed during the tows, and sometimes the values were outside the range of possible values. This is cause by poor signal to noise ratio, and sometimes it was due to twisted sensor attachment. Also deflated battery in the sensors caused lost measurements.

In general the quality of the doorspread measurements were excellent as well as the depth measurements of the groundrope (practically in 100% of the tows). The horizontal spread of the trawl opening was the most troublesome to measure, as the sensors were attached to the side-net, and were easily twisted during shooting of the trawl, and also because the net in the side portion of the trawl might be unstable during towing. For the measurements of the underwing the challenge was to get the sensors aligned towards each other so the distance could be measured during towing. A special metal chasing was developed to place the sensor inside for protection and also to be able to attach them to the extension chain just in front of the underwing (Fig. 4).

Based on the present attempts to monitor the trawl gear during pelagic surface trawling in order to make a comprehensive swept area estimate, it is recommended to continuously monitor and measure the spread between the trawl doors and the spread of the underwings, and also monitor the width of the trawl opening, if possible.

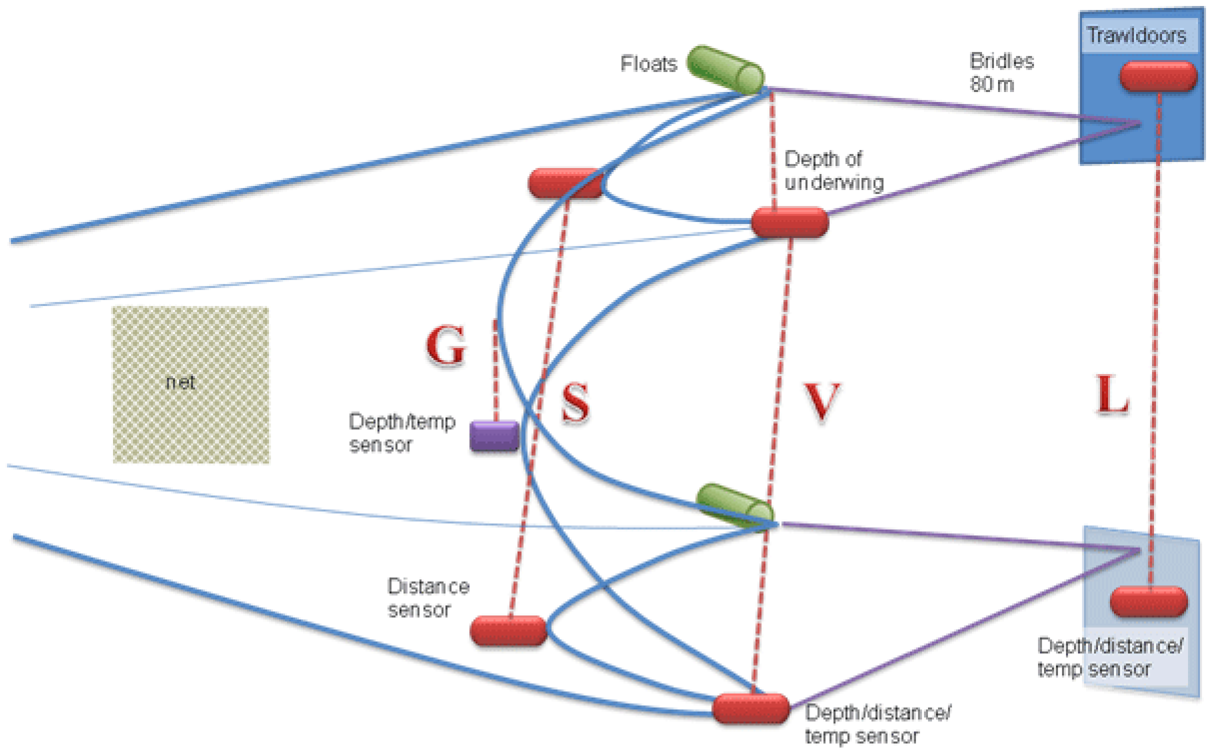


Figure 1. Sensor arrangement and attachment on the Faroese Multpelt 832 sampling trawl for mackerel. Four measurements were made in the trawl. A pair of distance sensors were put on trawl doors (L), a pair on the underwings (V), and a pair on the sidenet in the trawl opening (S). A depth sensor was attached to the groundrope (G) to measure the vertical spread of the trawl opening.

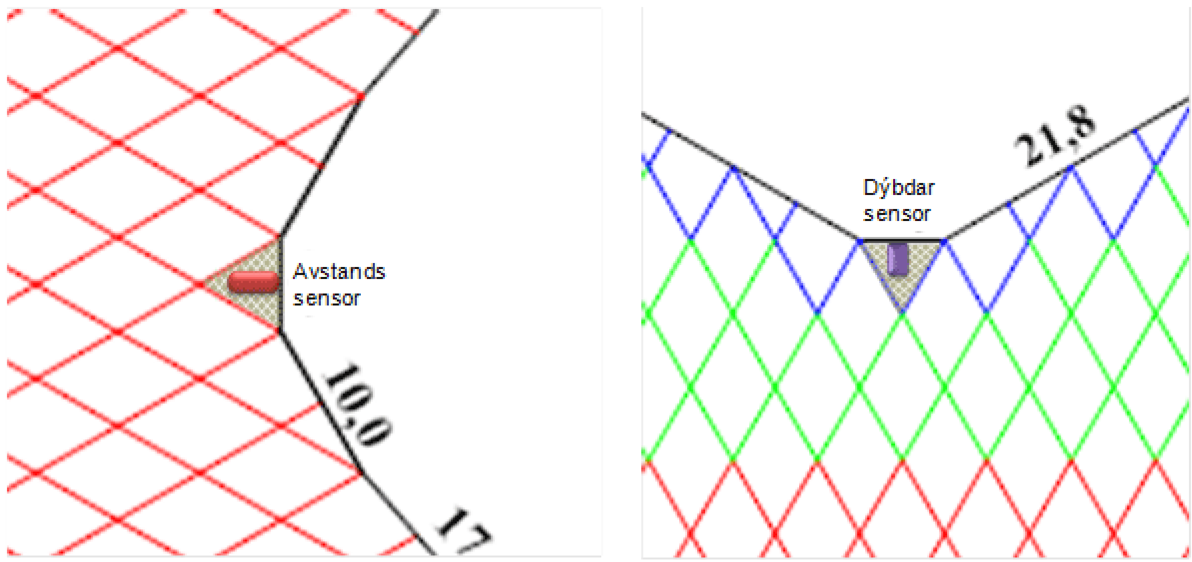


Figure 2. Sensor attachment in the trawl opening. Left panel: Distance sensors on the side-net to measure horizontal trawl opening (S). Right panel: depth/temperature sensor on the groundrope (G).

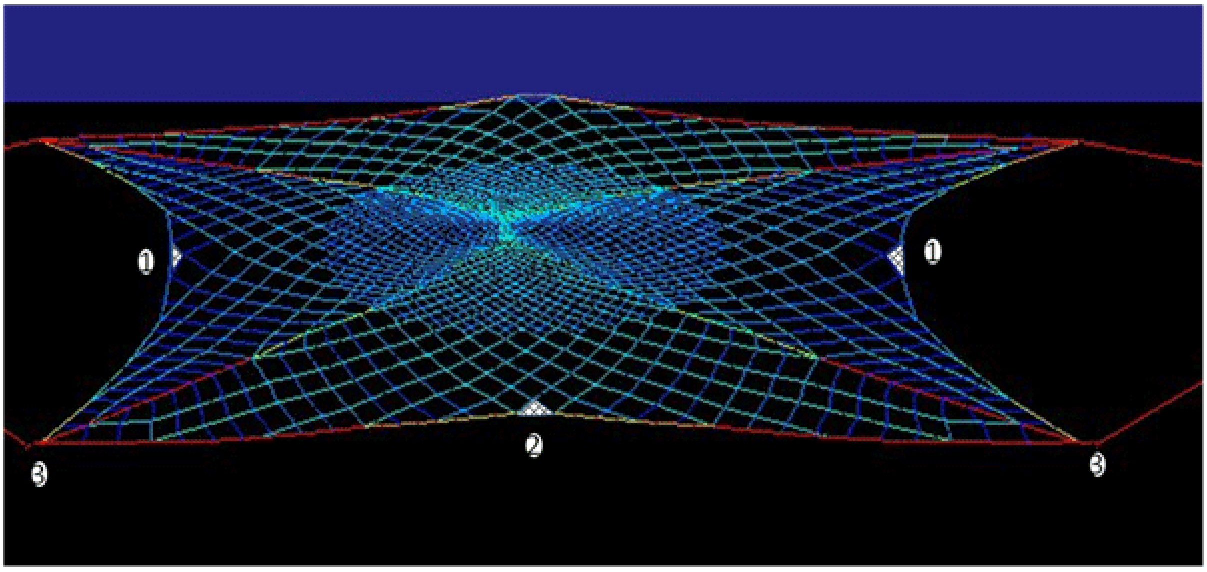


Figure 3. Placement of the sensors on the Multpelt trawl 1) distance sensors in the trawl opening (S), 2) depth sensor on the groundrope (G), and 3) distance sensors on the underwings (V).

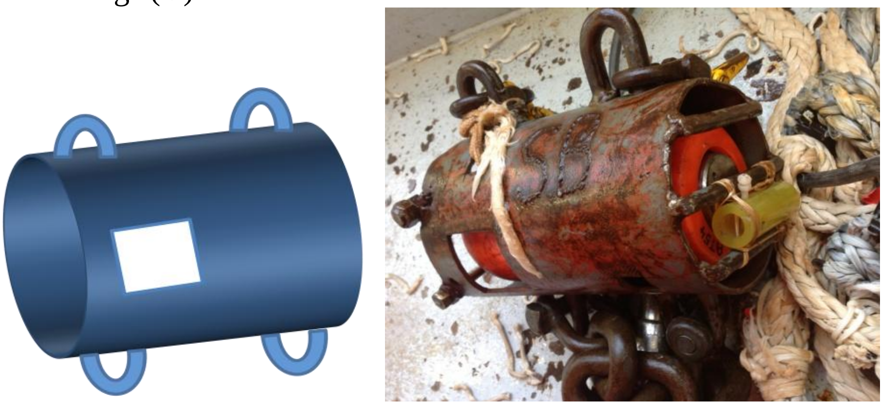


Figure 4. Metal chasing to hold and protect the distance sensors attached to the underwings (V). Left, drawing and right photograph.

Table 1. Gear parametres for the Faroese Finnur Fríði during the international mackerel survey in July 2013 (IESSNS). Four set of sensors (Fig. 1 and 3) were monitored continuously during each haul for the whole survey (37 trawl stations). The four set of sensors measured the door spread, spread of the underwings, width of the trawl opening (side-net), and depth of the groundrope. The width of the trawl opening and spread of the underwing was not always recorded due to either poor connection up to the vessel or twisted position of the sensors during the shooting process of the trawl.

Measurement	FO	(SD)	N
Doorspread (L)	110.5	5.6	37
Underwing (spread) (v)	76	8.7	25
Width of trawlopening (side-net) (S)	59.2	5.5	25
Depth of groundrope (G)	35.6	3.7	36
Trawl speed	4.9	0.3	37

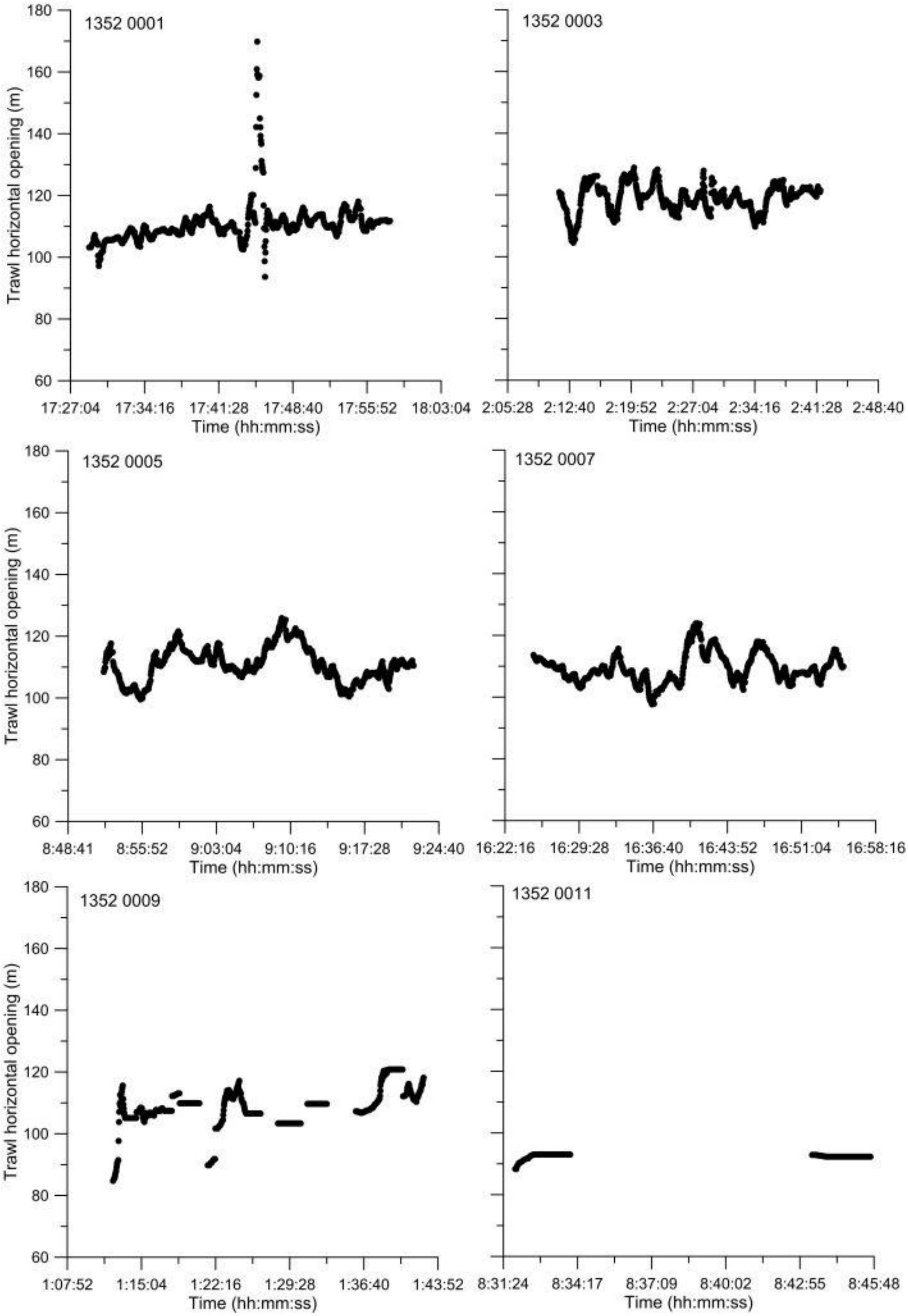


Fig. 5. Door spread (m) by trawlstation (duration 30 min) on the Faroese Finnur Fríði, mackerel survey July 2013.

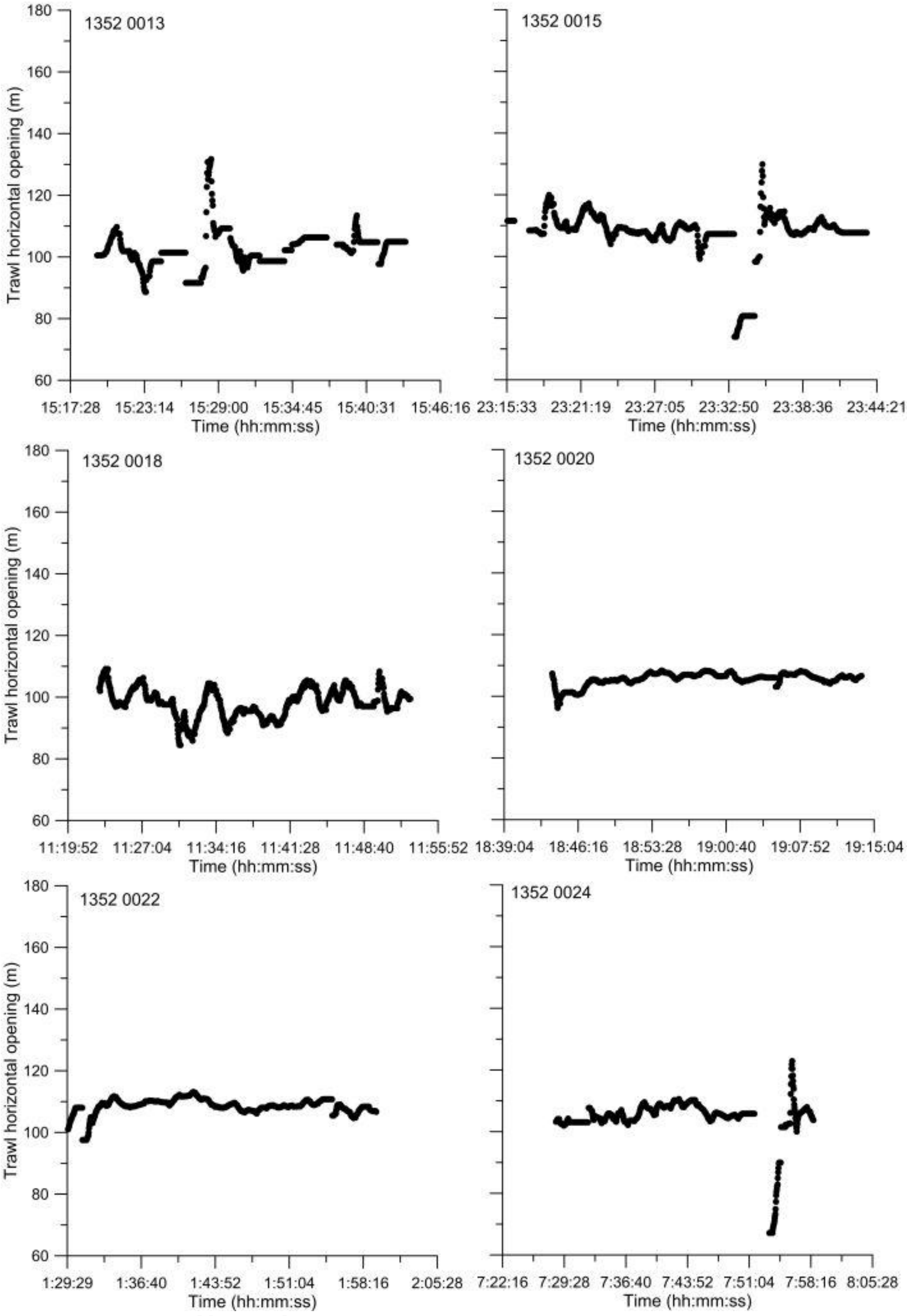


Figure 5. Doorspread by trawlstation, cont.

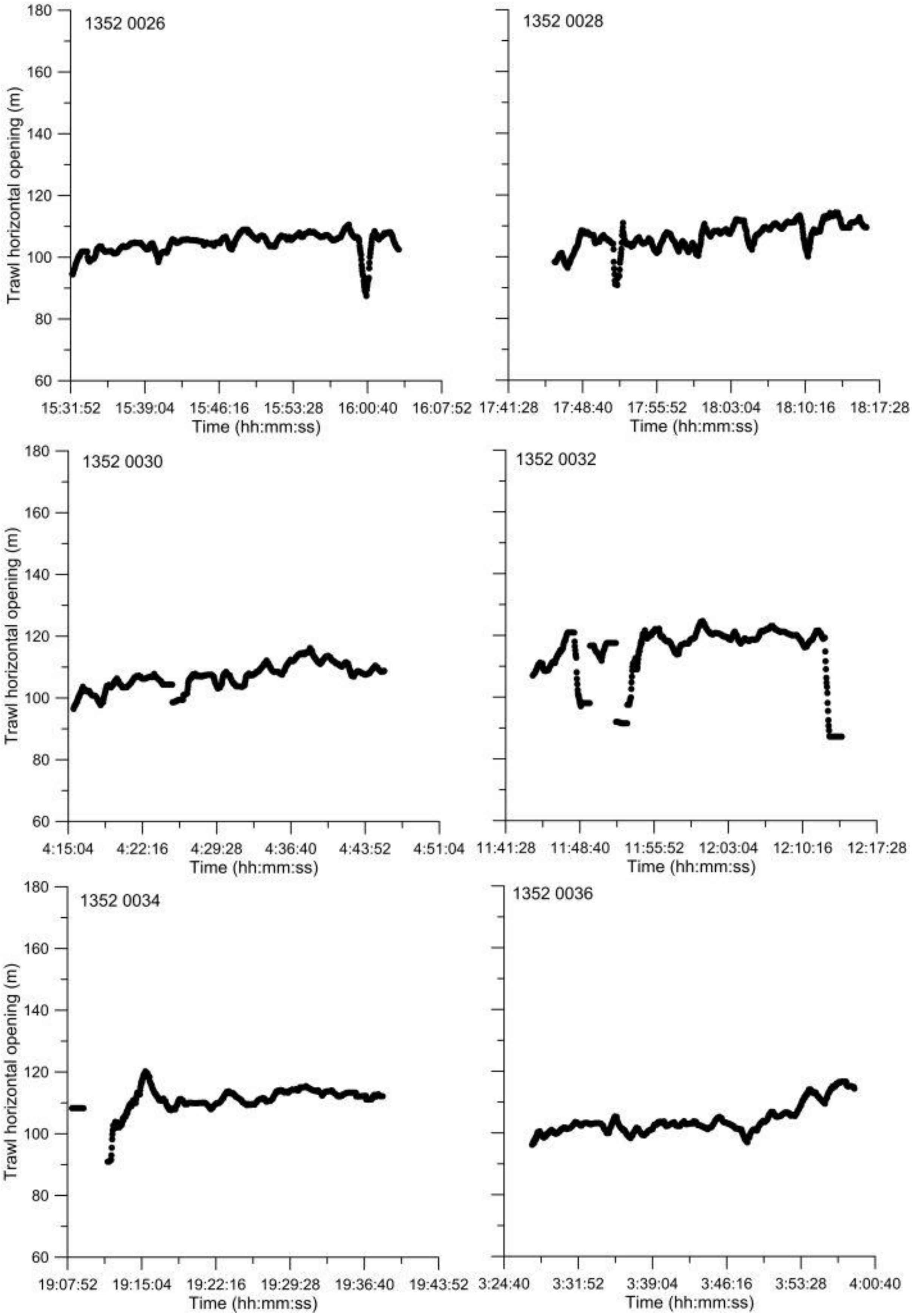


Figure 5. Doorspread by trawlstation, cont.

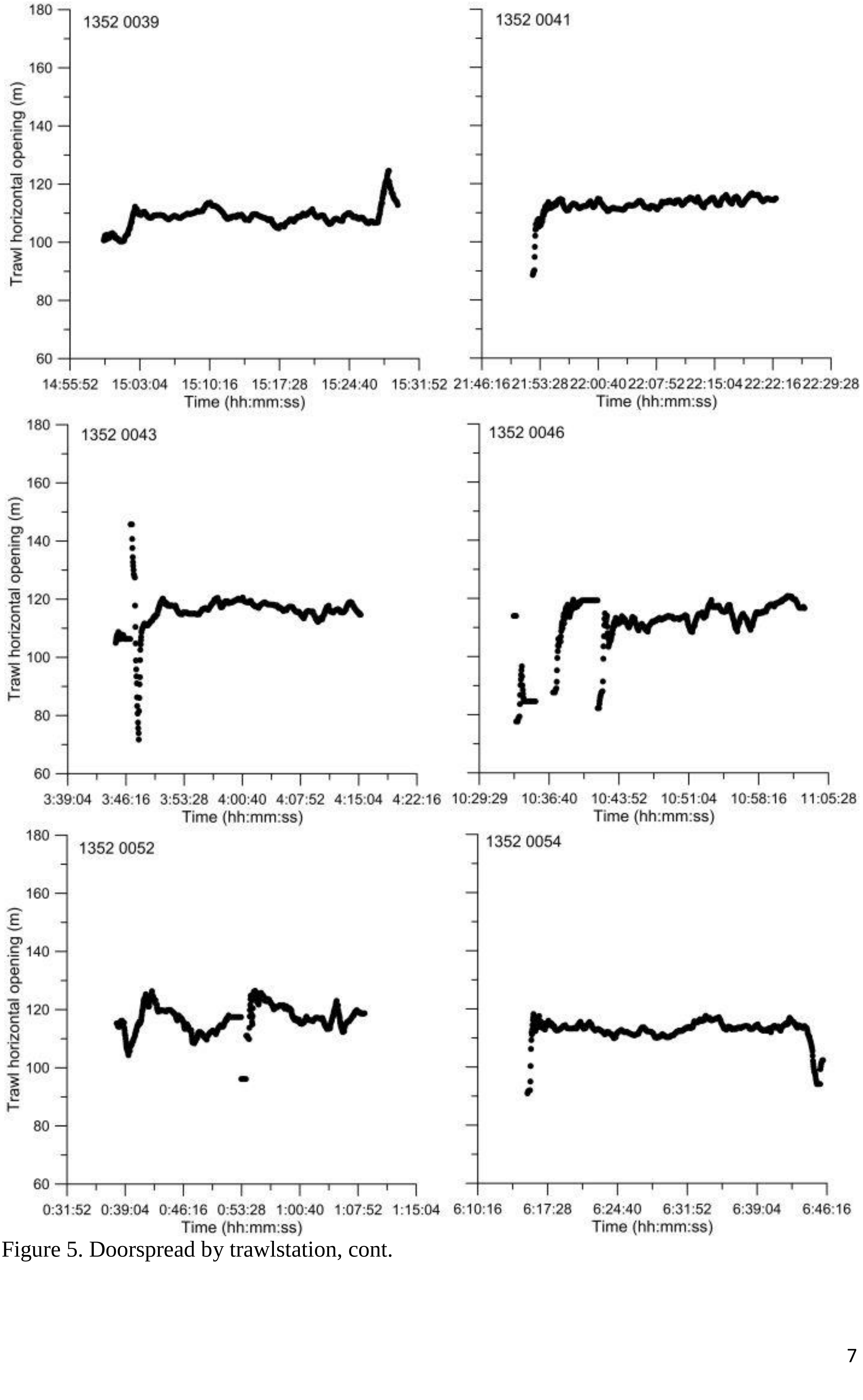


Figure 5. Doorspread by trawlstation, cont.

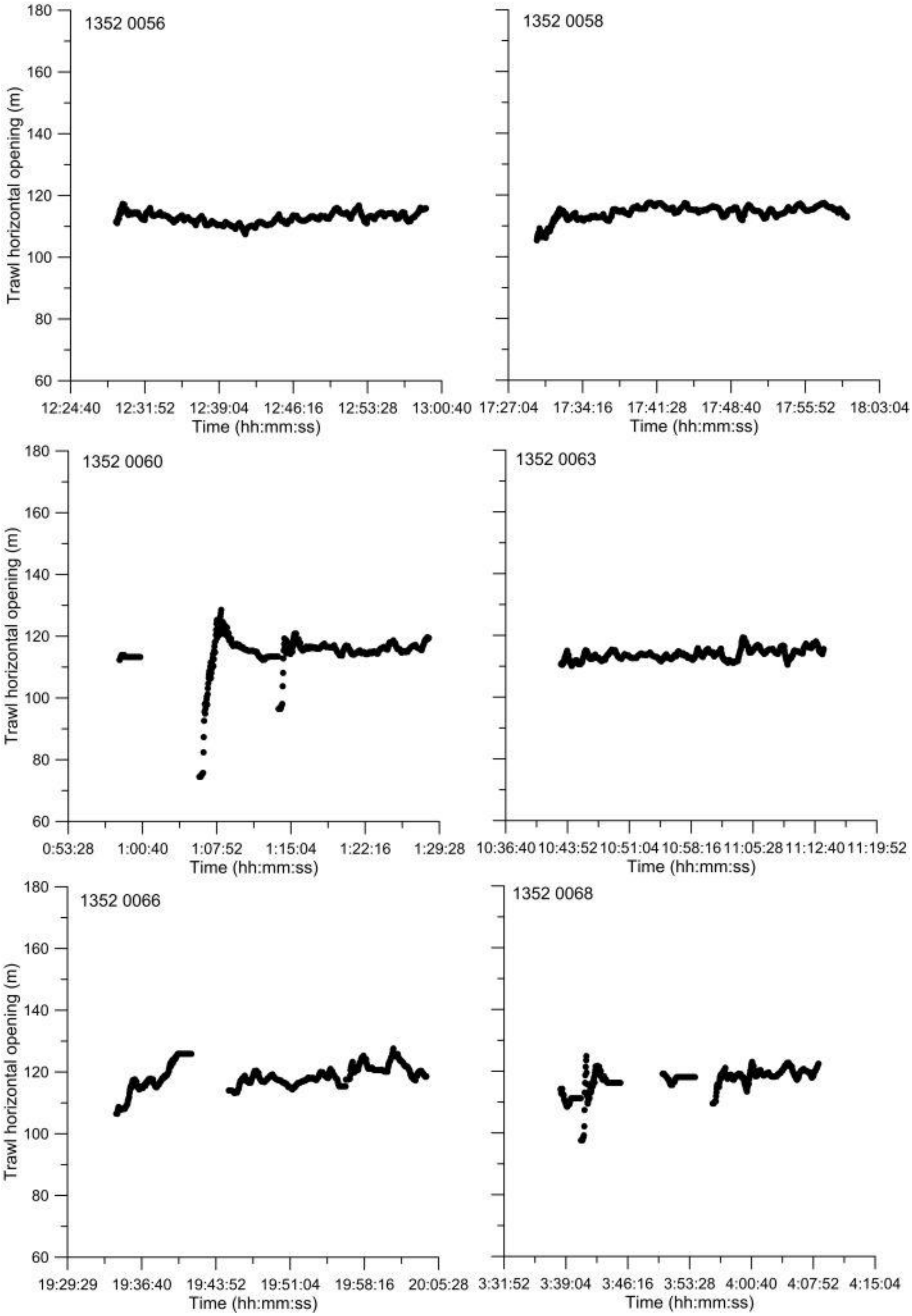


Figure 5. Doorspread by trawlstation, cont.

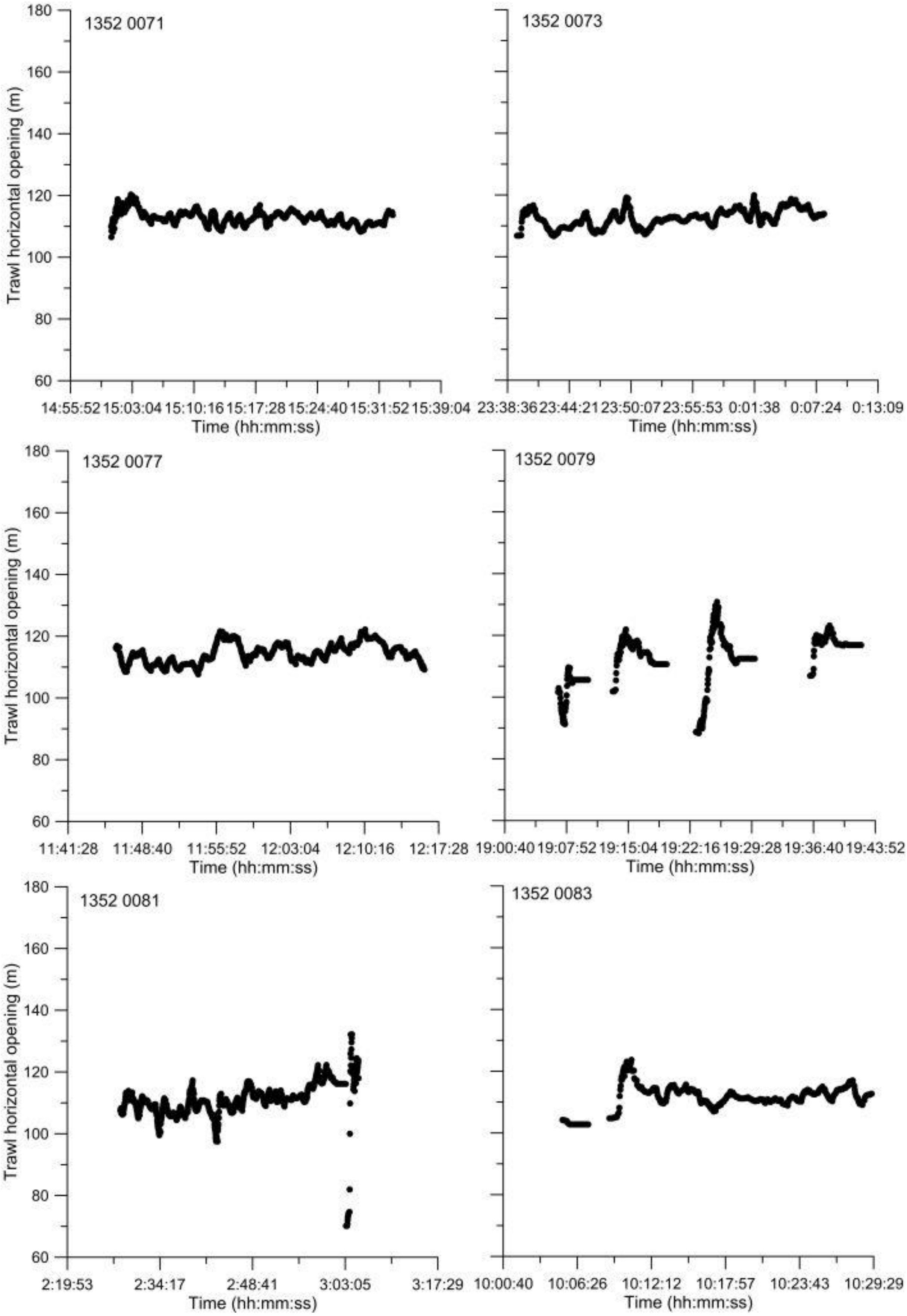


Figure 5. Doorspread by trawlstation, cont.

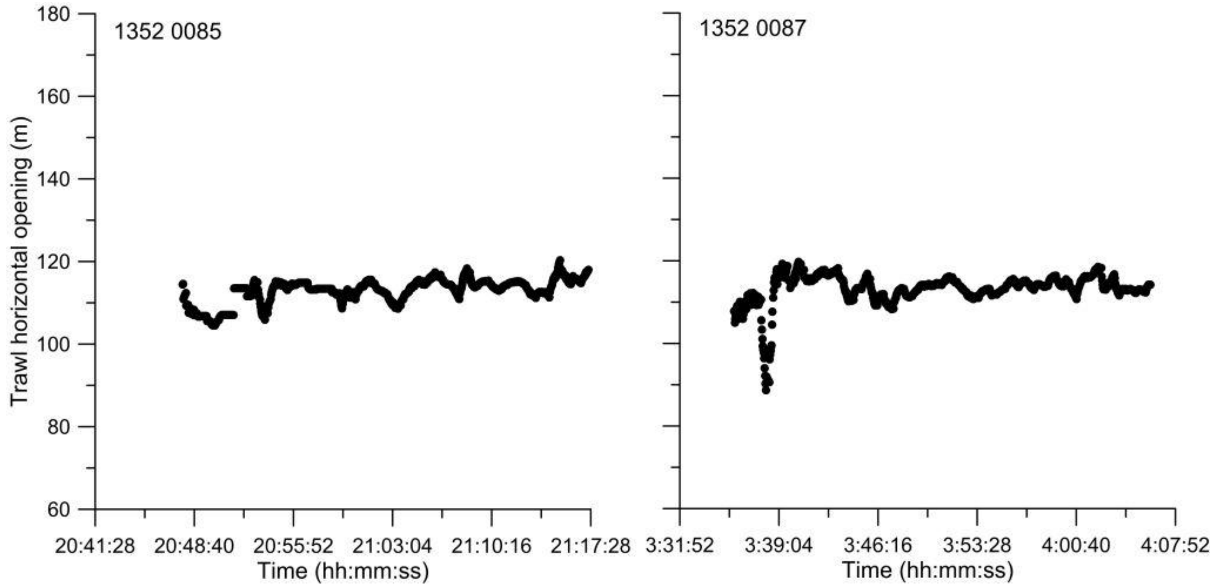


Figure 5. Doorspread by trawlstation, cont.

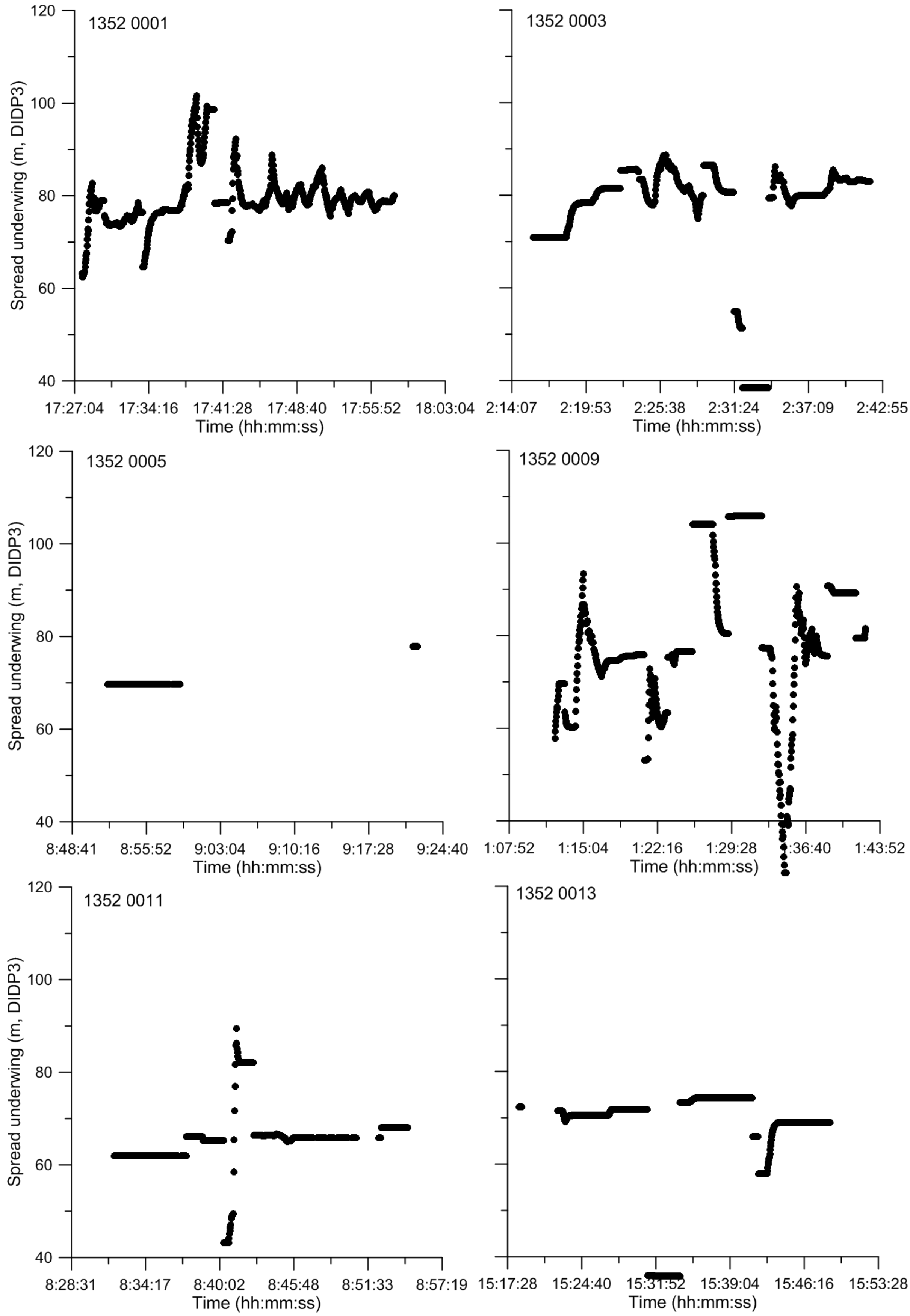


Figure 6. Spread of the underwings by station from the Faroese Finnur Fríði, mackerel survey July 2013.

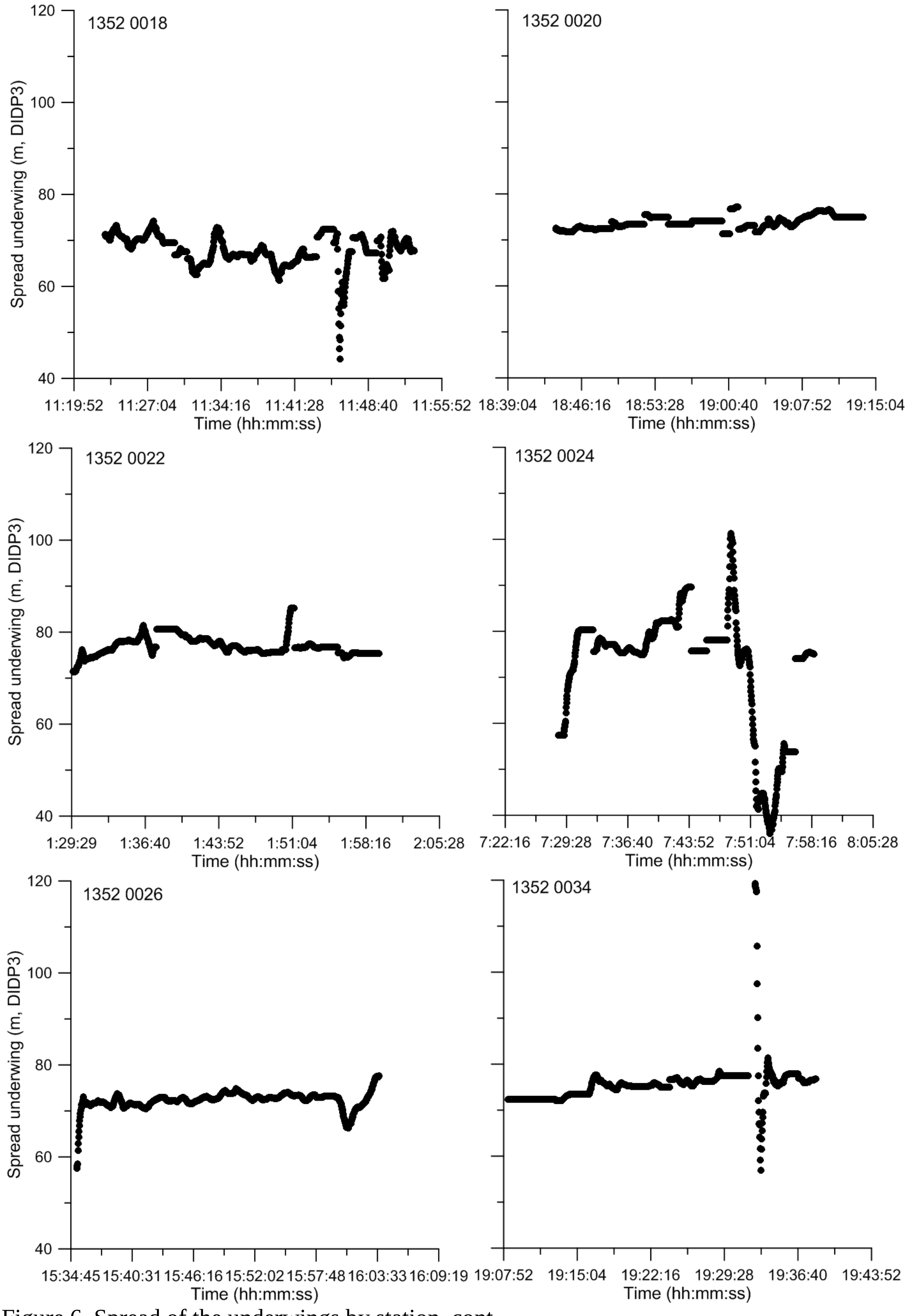


Figure 6. Spread of the underwings by station, cont.

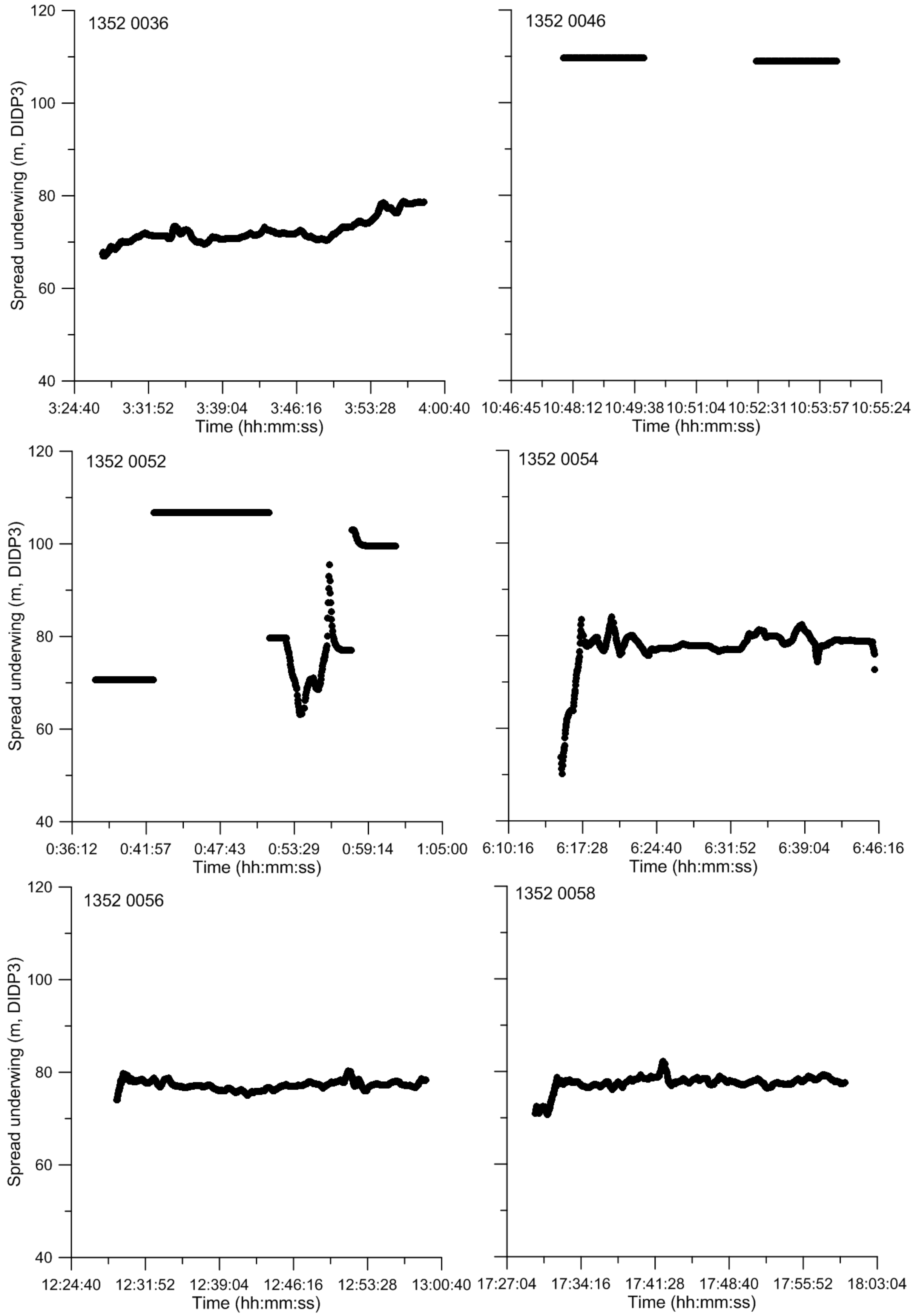


Figure 6. Spread of the underwings by station, cont.

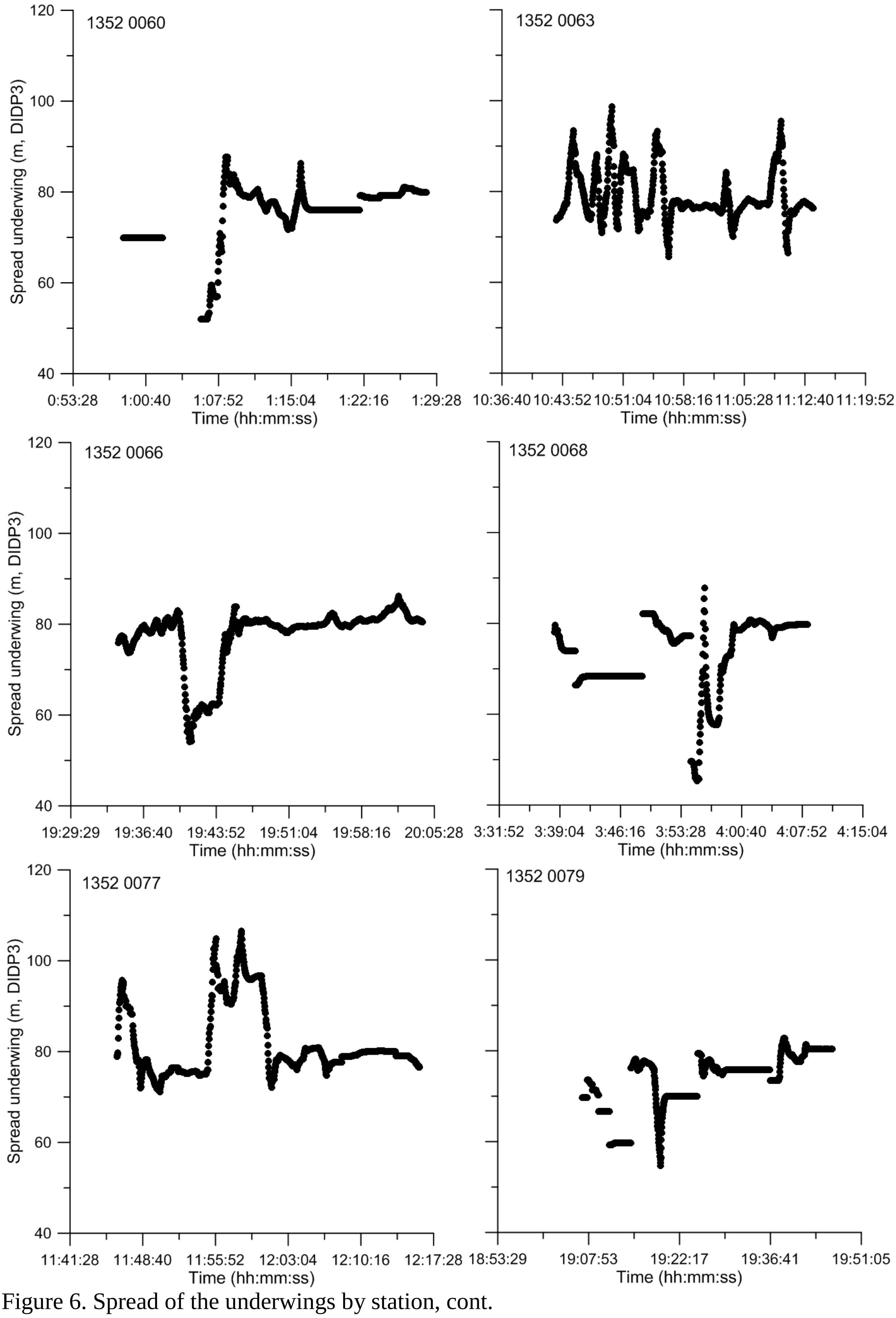


Figure 6. Spread of the underwings by station, cont.

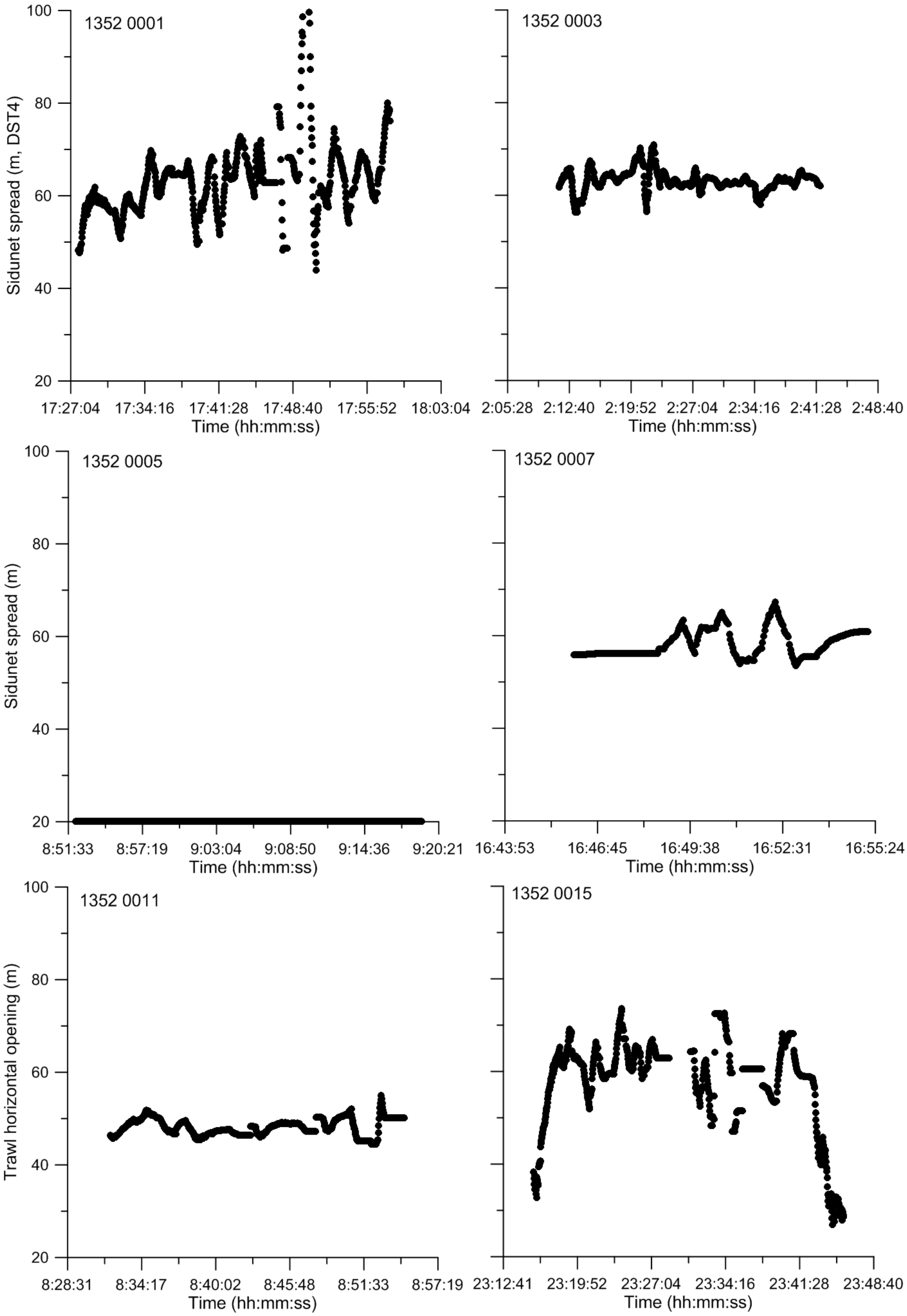


Figure 7. Width of the trawl opening by station from the Faroese Finnur Fríði, mackerel survey July 2013.

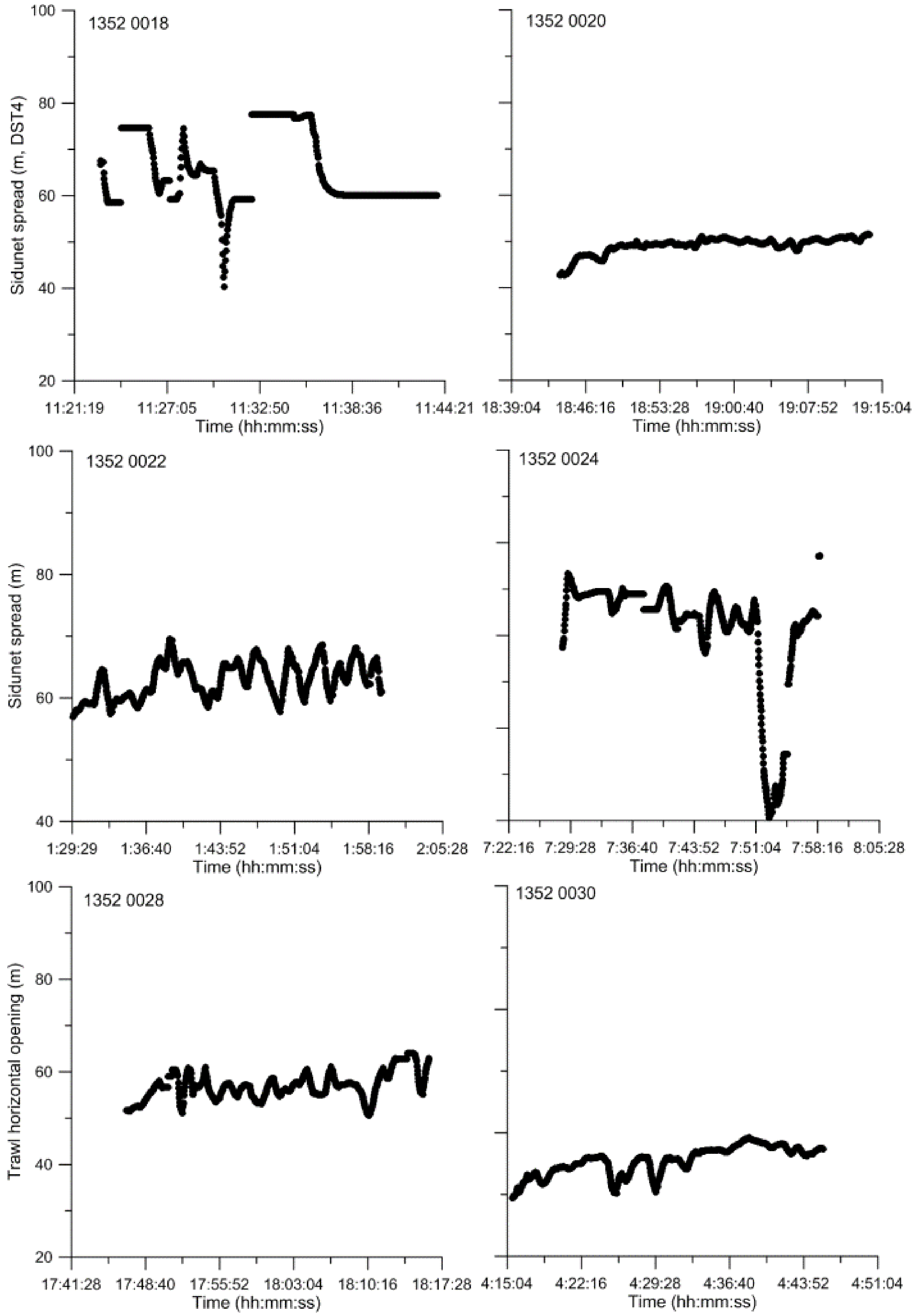
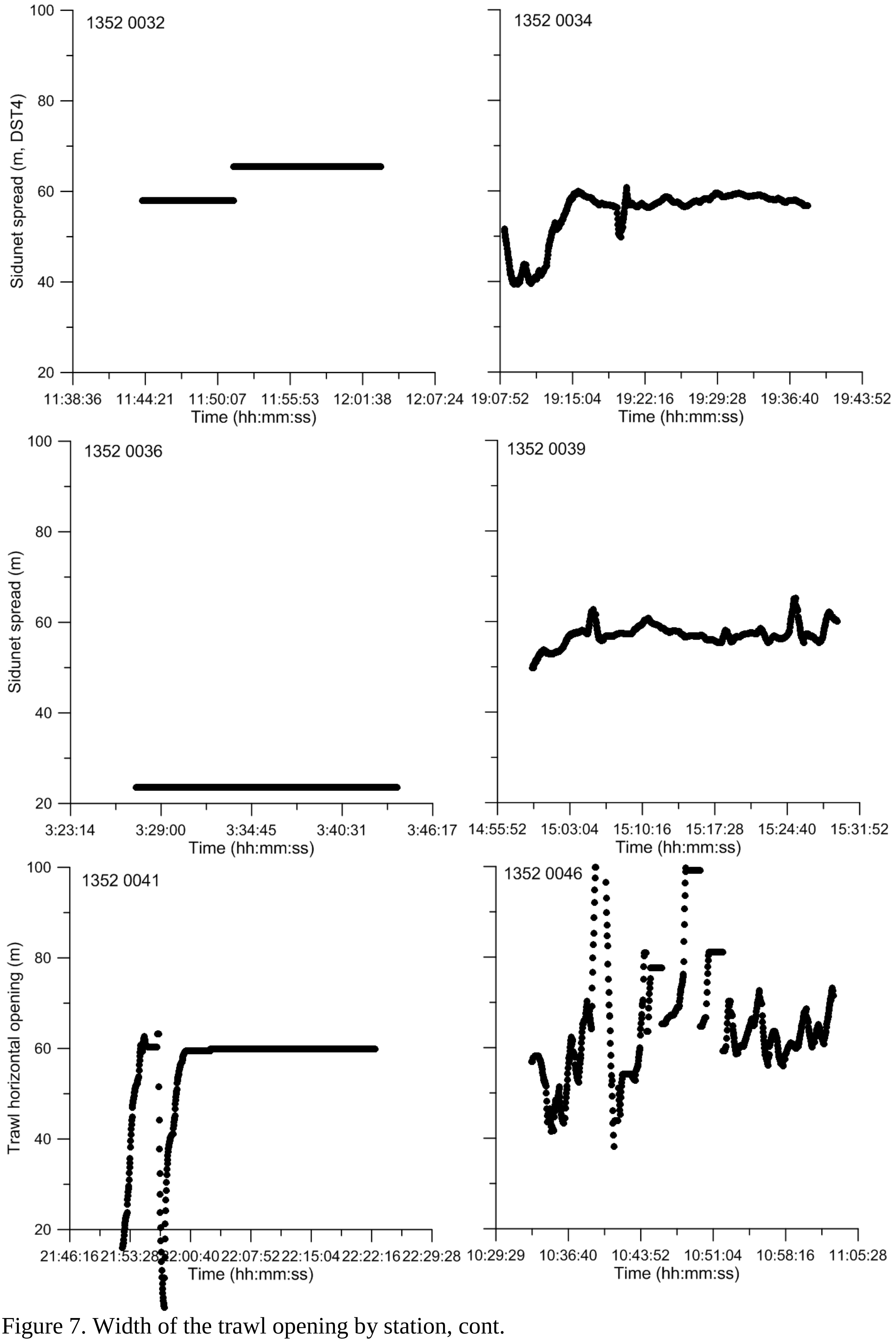


Figure 7. Width of the trawl opening by station, cont.



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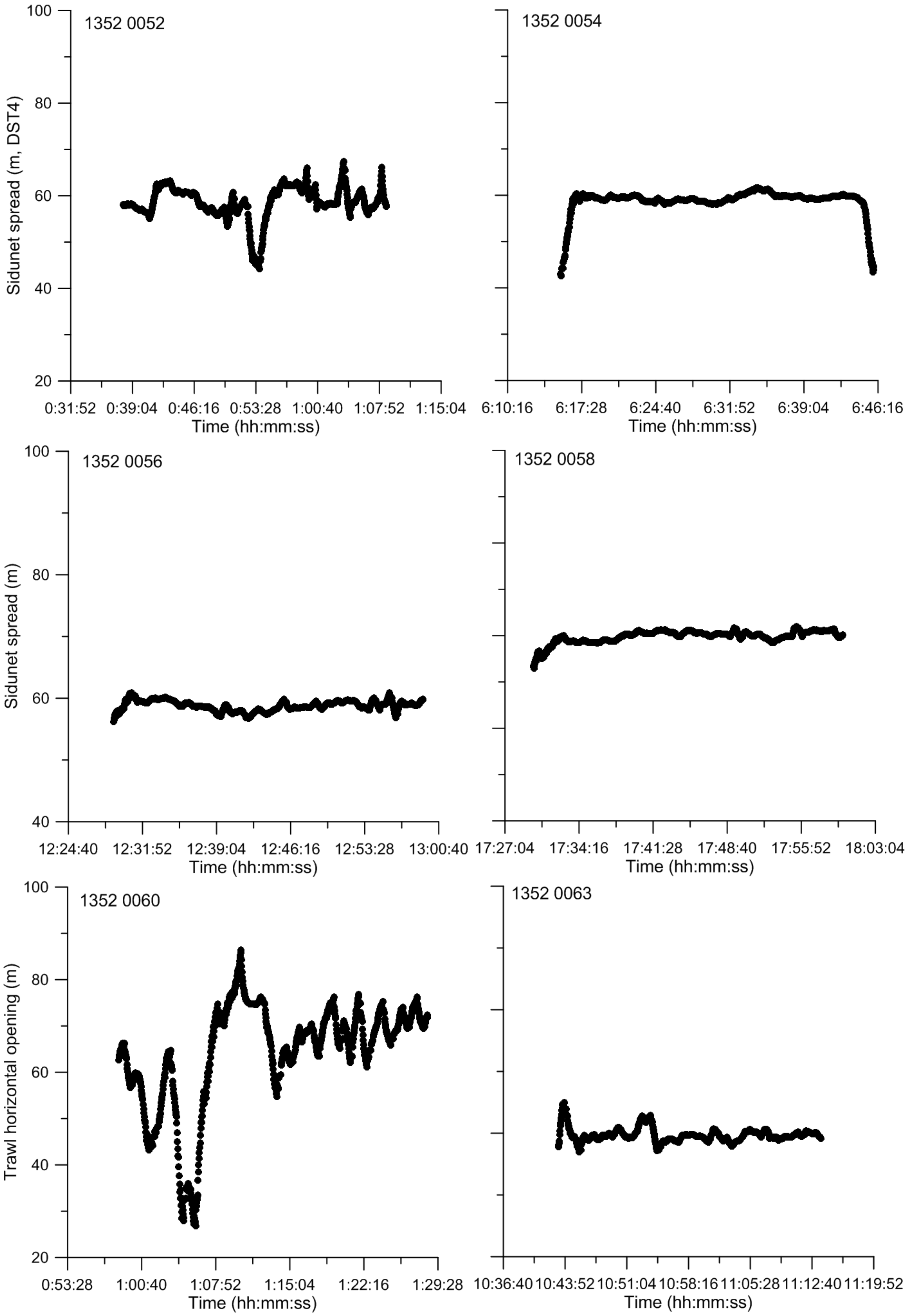
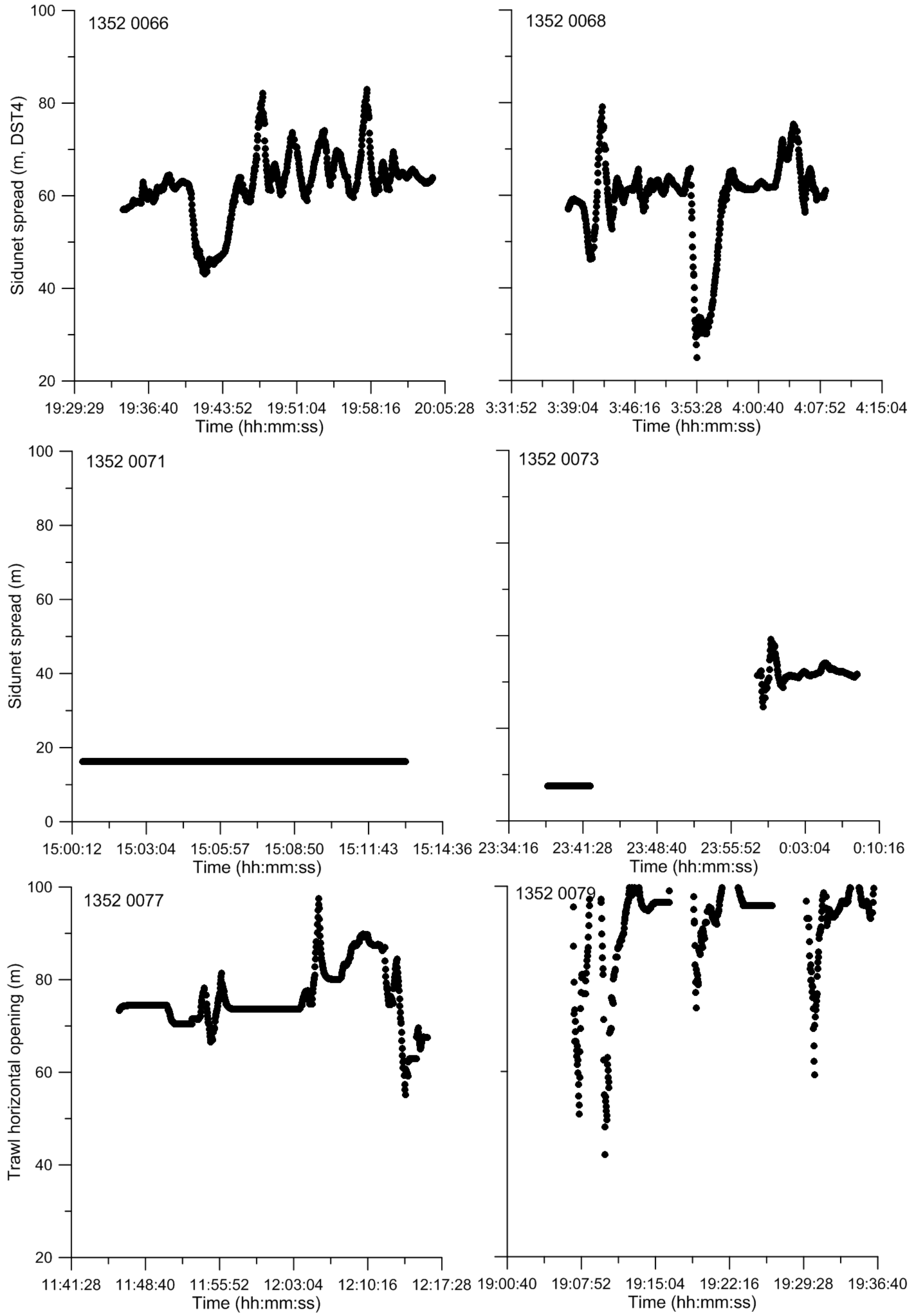


Figure 7. Width of the trawl opening by station, cont.



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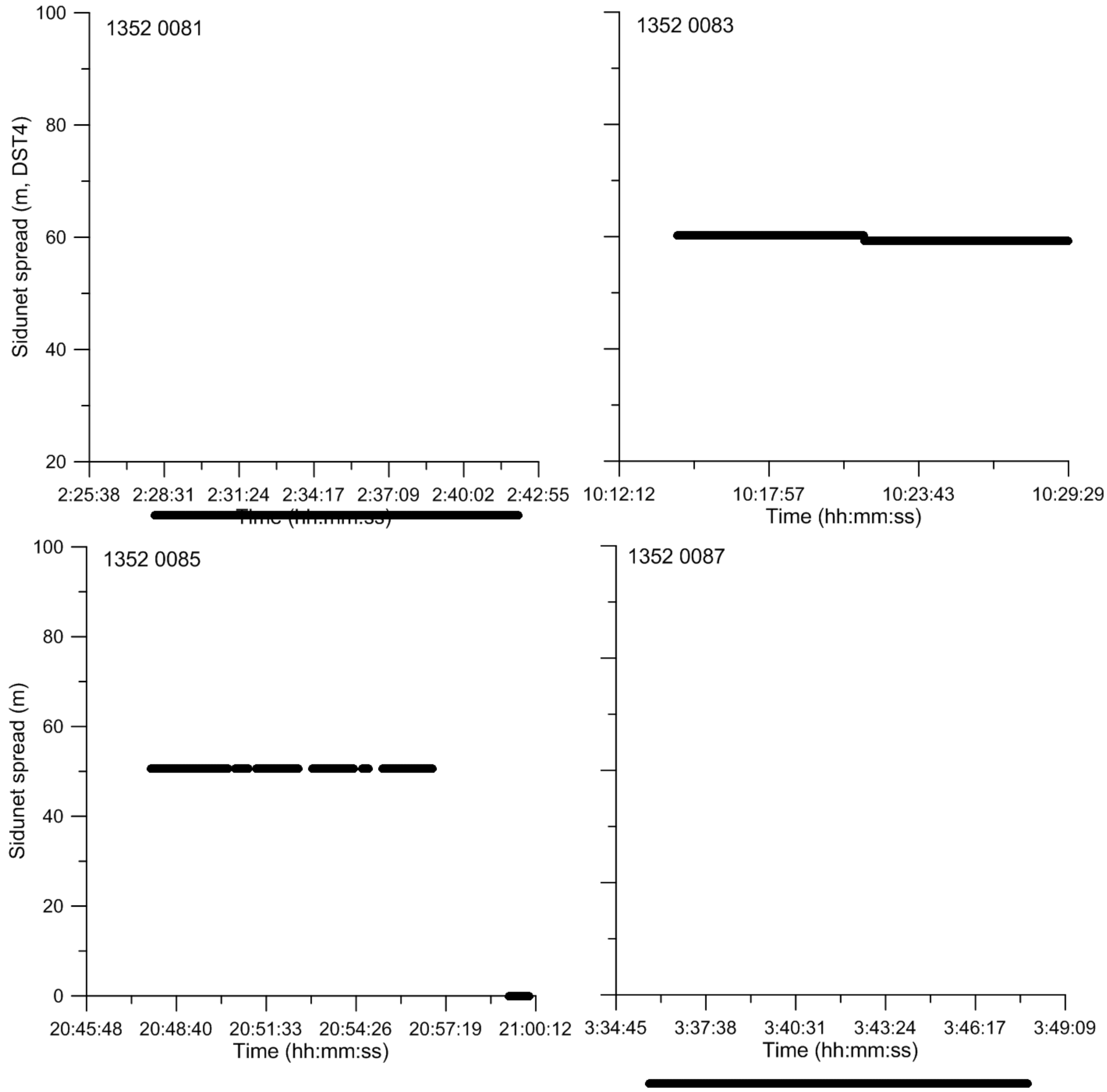

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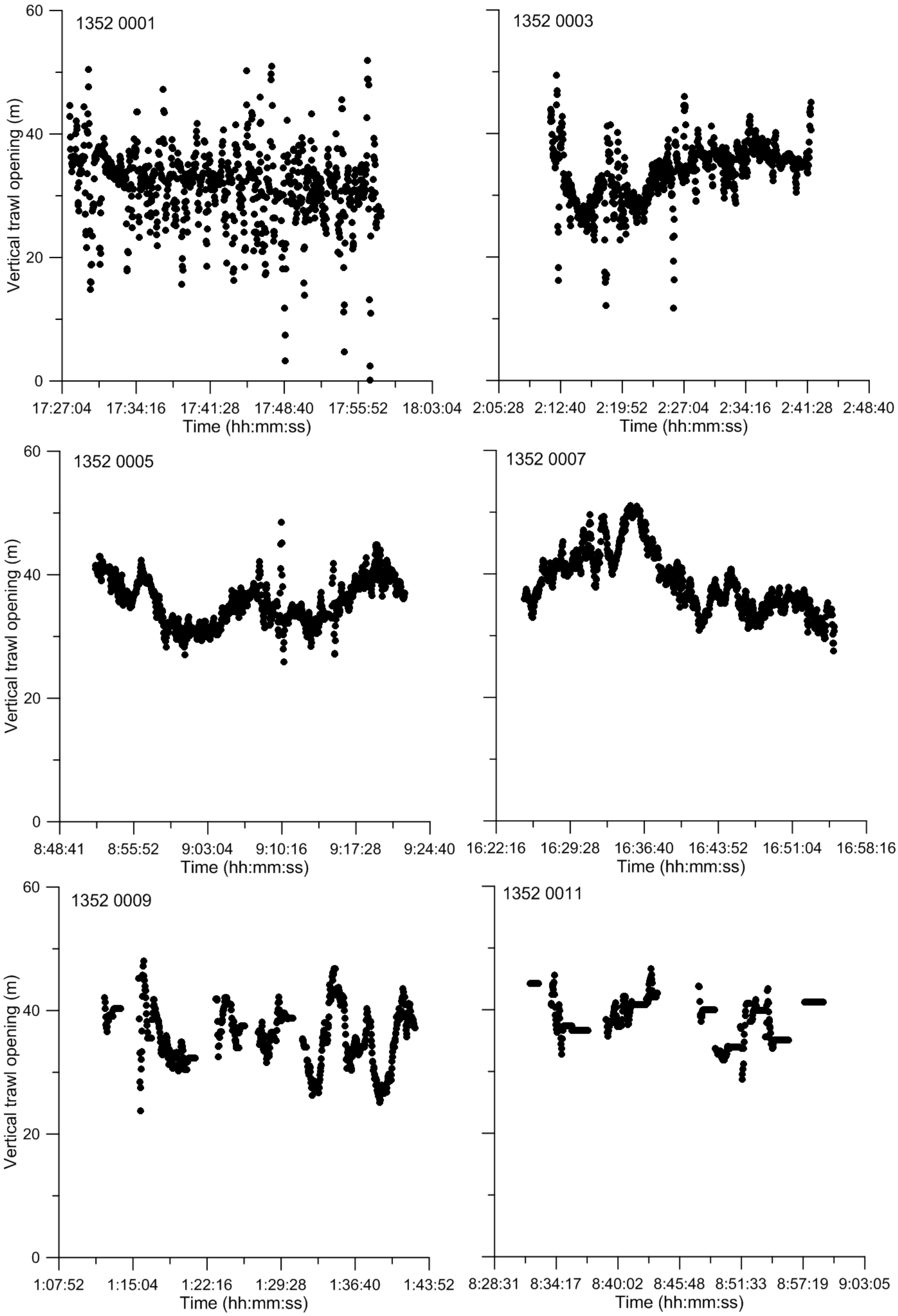


Figure 8. Depth of the groundrope by station from the Faroese Finnur Fríði, mackerel survey July 2013.

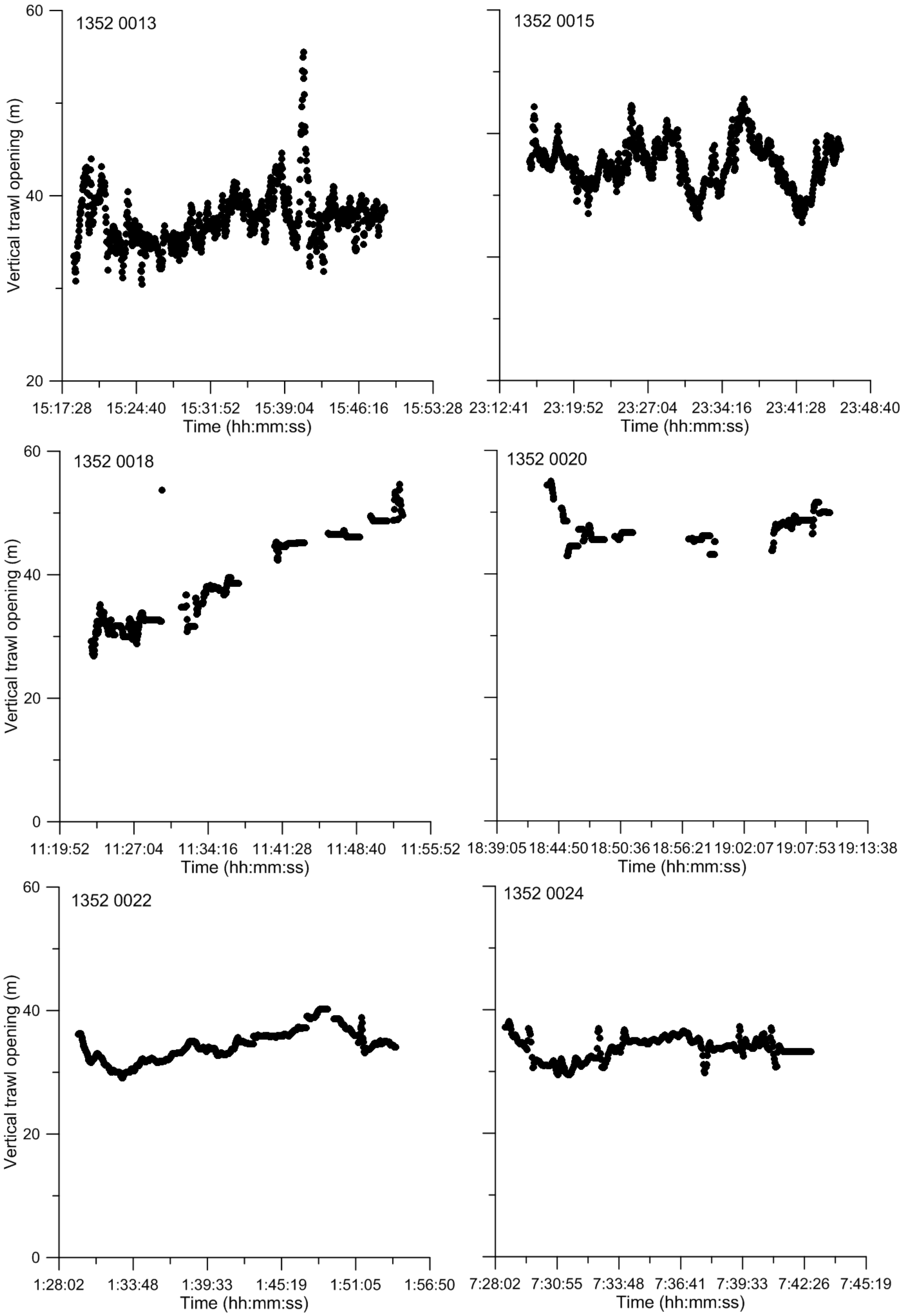
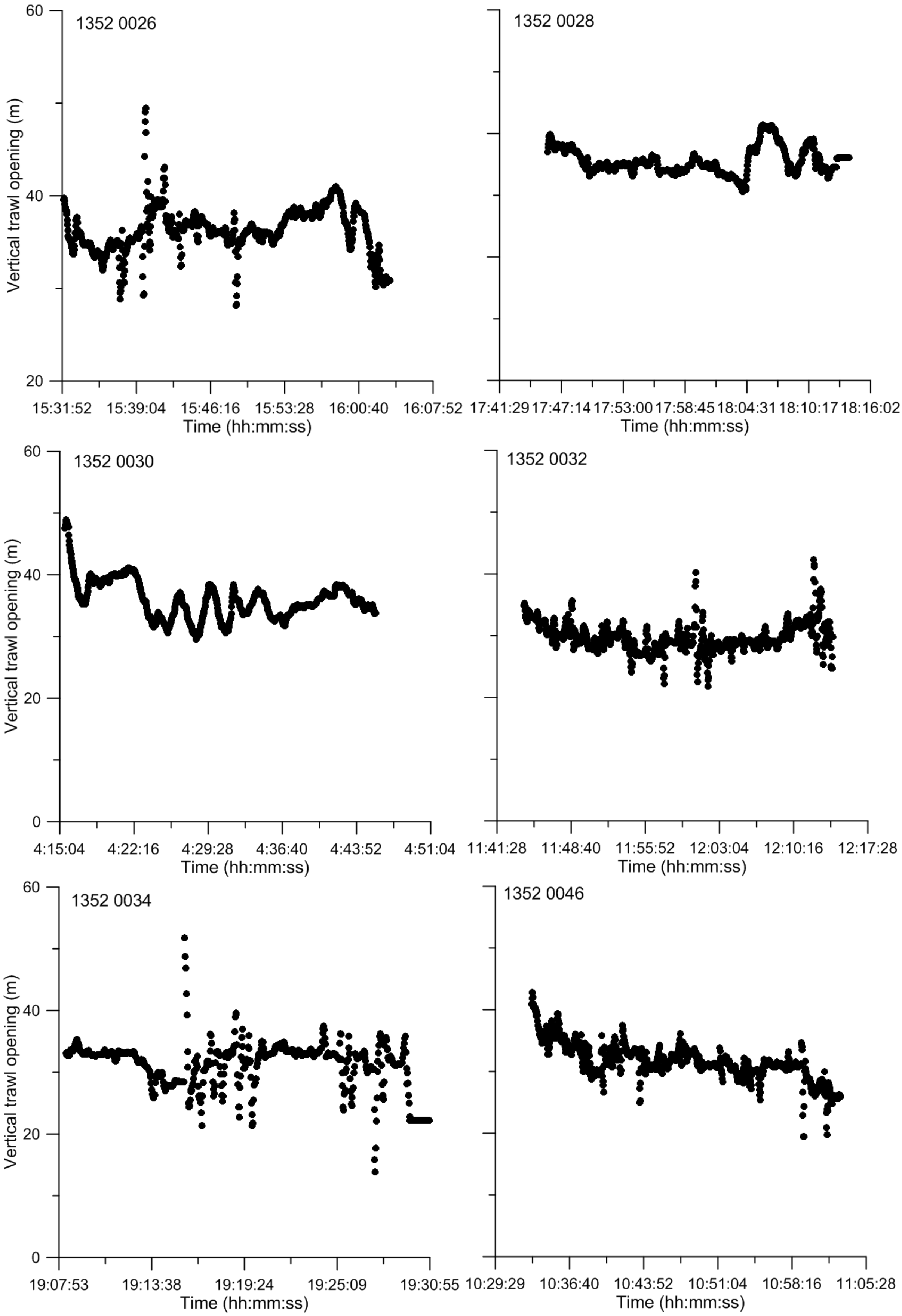


Figure 8. Depth of the groundrope by station, cont.



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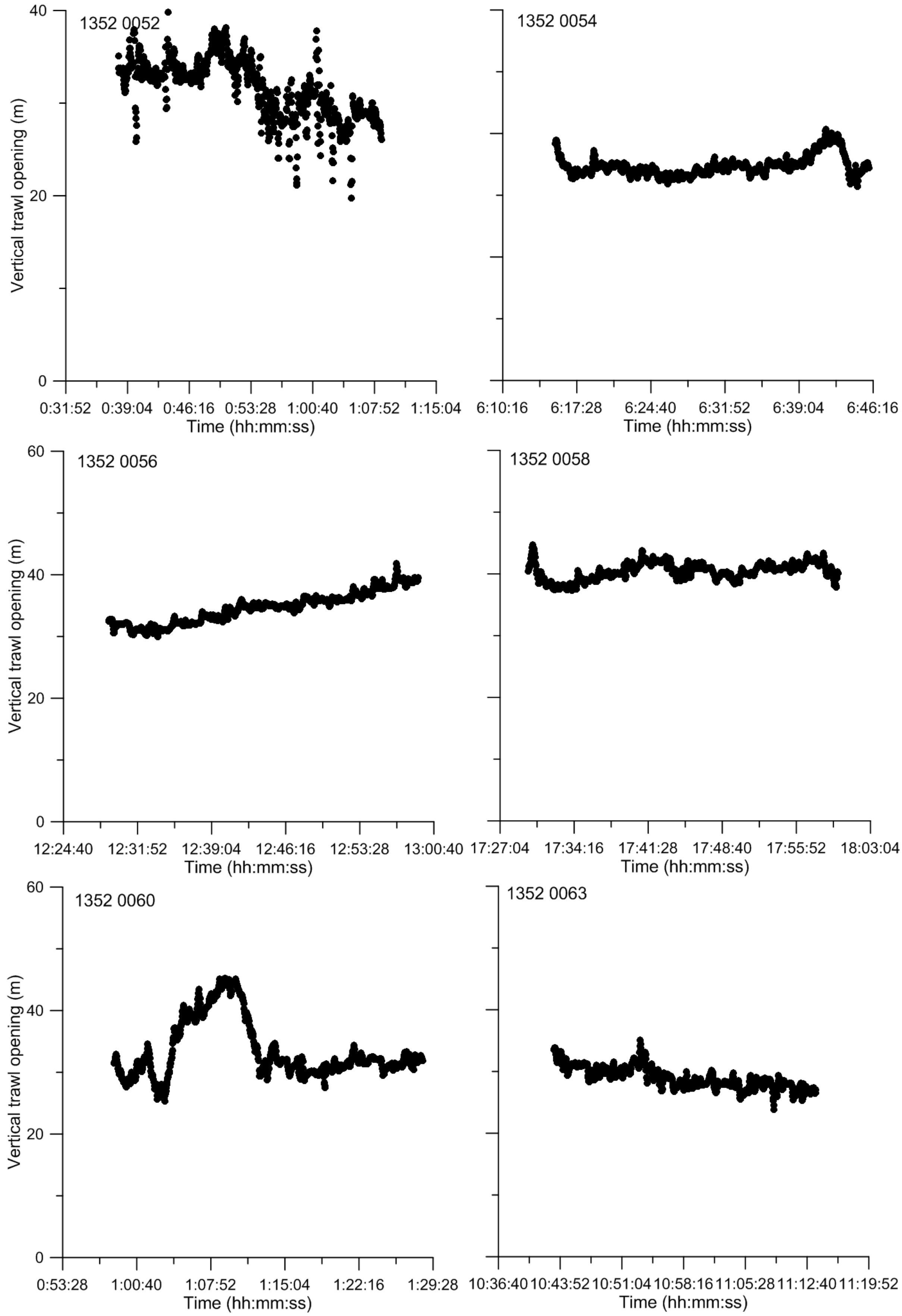

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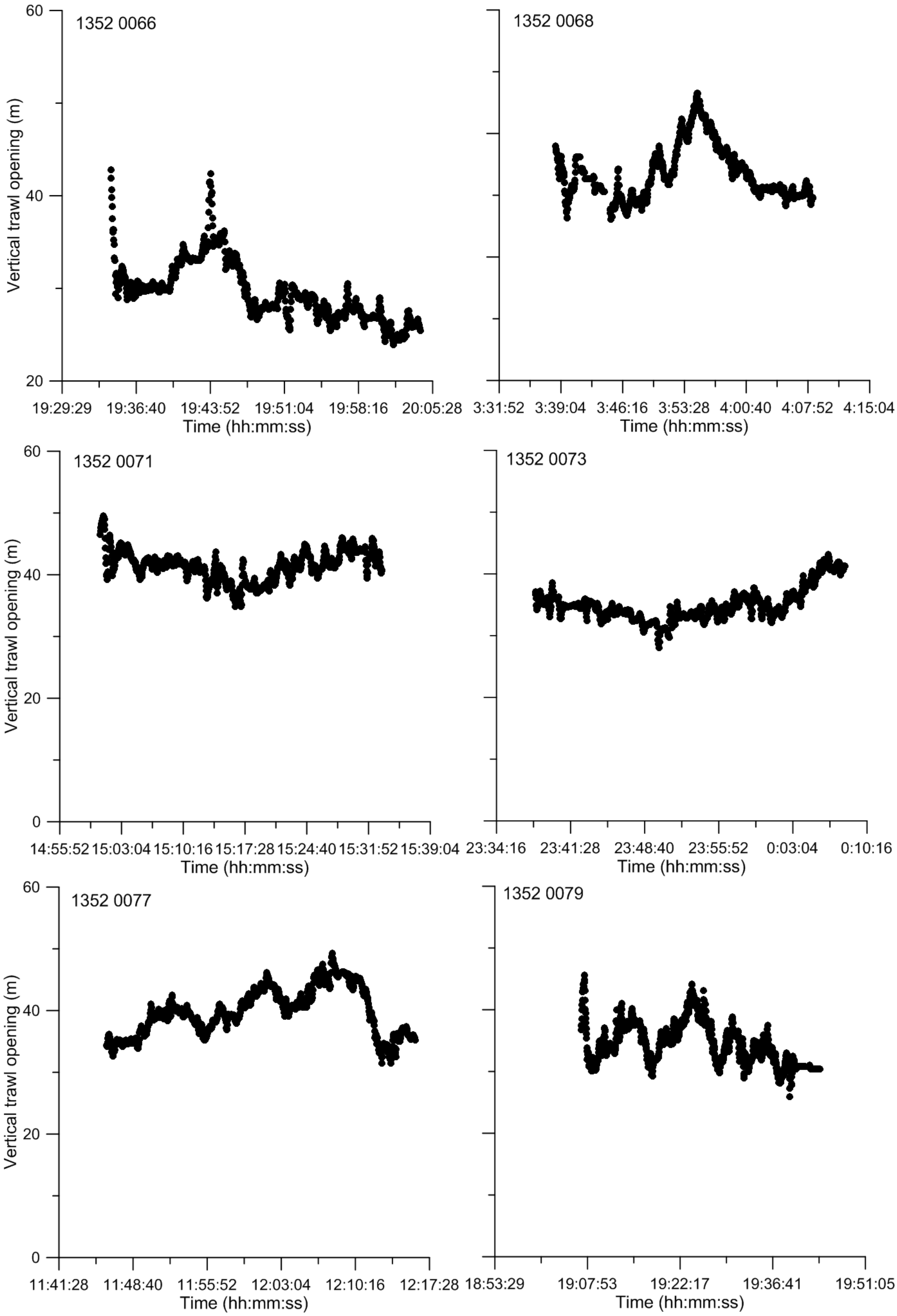

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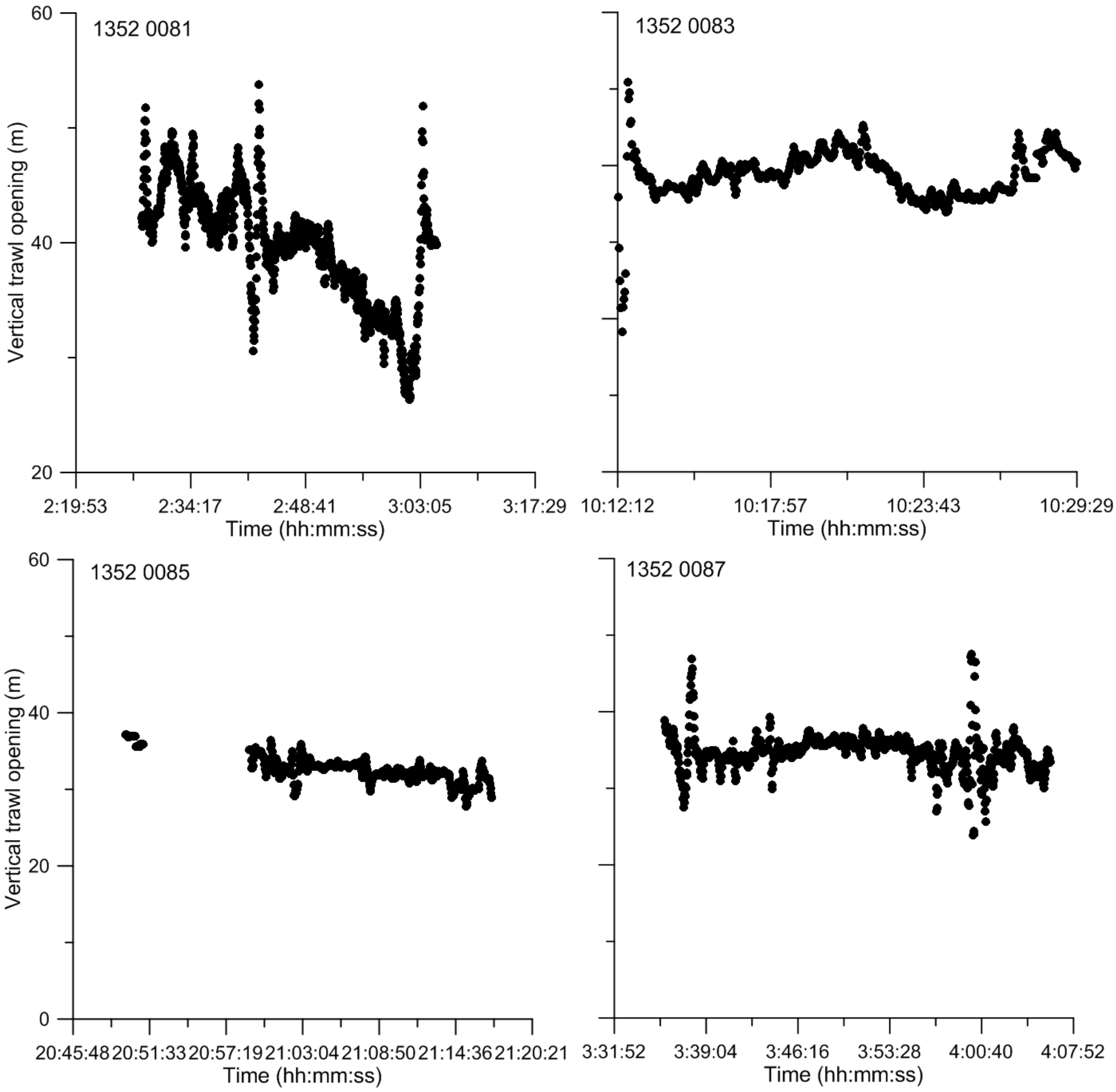

Figure 8. Depth of the groundrope by station, cont.

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DISCARDED MACKEREL IN SPANISH FISHERIES (ICES Divisions Via-b, VIIb-c-g-h-j-k, VIIIc, IXaN and IXaS)

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Material and methods

Sampling strategy

The sampling strategy and the estimation methodology used in the "Spanish Discards Sampling Programme" has been little modified since 1994, and since 2003 follows the guidelines established by ICES (ICES, 2003) and raising procedure is based in ICES, 2007.

The observers-on-board programme is based on a hierarchical sampling design, applied to strata defined by two dimensions. Year was considered the strata unit for the temporal dimension until 2009, when the DCF asked for quarterly estimates. Herein results from 2012 are organised and presented at quarterly basis. The second sampling dimension is technical, and the strata unit is the Métier. In regards to the sampling units, trips (the Primary Sampling Unit [PSU]) are randomly or quasi-randomly selected from the bidimensional strata. Once onboard, the observer systematically select hauls for sampling, (the Secondary Sampling Unit [SSU]) when the total number of hauls is expected to be high during the sampled trip; otherwise, all hauls are sampled. The Ultimate Sampled Unit (USU) is the numbers of individuals by species found in discard sample.

Only trawl fleet and purse seiner fleet from IXaS zone information are used in this document. Other fleets (i.e. long line or purse seine fleet in northern VIIIc and IXaN) were evaluated, showing very low discards along the areas under study (Pérez et al., 1996). Gillnet discard information is being obtained since 2008, but the time series available has been considered too short to be presented in the present document.

Discard value are estimated per métier and Divisions (VIIb, Divisions VIIc-j, Division VIIk, Division VIIIc, Sub-Division IXaN and Sub-Division IXaS) separately. Fishing area, gear and target species are the auxiliary covariates used to stratify fleets into métiers. Two Spanish trawl métiers are defined in the ICES Subareas VI and VII (Bellido and Pérez, 2007):

-OTB_DEF_70-99_0_0 trips targeting Megrim, Monk and Hake

-OTB_DEF_100-119_0_0 trips targeting Hake and Monk

More complex structure is found for the Spanish trawl fleet operating in ICES Divisions VIIIc and IXa North:

-OTB DEF>=55_0_0: trips targeting a mixed of demersal species using conventional OTB gears

-OTB_MPD>=55_0_0: trips targeting a mixed of pelagic and demersal species using high vertical opening OTB gears

-PTB DEF >=55_0_0: trips targeting demersal species using bottom pair trawls
Finally, only two metiers were defined for the ICES Division IXa South:
-OTB MCD >=55_0_0: trips targeting demersal species using bottom pair trawls
-PS_SPF_0_0_0: trips targeting sardine using purse seiner

Discard estimates by métier have been aggregated into fishing ground level, in order to present total discards by the whole Spanish trawl fleets.

Sampling scheme & Raising procedures

Estimates of the discard weight was calculated from length distribution using length-weight relationships and raised to the total discard by trip. The haul-raised data were further raised to total hauls in the trip (total hauls in trip/sampled hauls in trip).

From the two methods to raising discards considered, a ratio estimator and a simple estimator (Borges, 2005; ICES, 2007), a simple estimator, number of fishing trips, was chosen for raising procedure based on the accuracy they might give and also on their availability.

Quantification of discards

For each haul an estimate of the total catch is made in kilograms, based on the total volume of the bottom trawl codend by the skipper or a crew member based on the amount of the fish in the hopper tank. The catch is sorted into species by the crew along a conveyor. The retained fish is saved and sorted into fish boxes. Several species (hake, monkfish) can be graded by sizes and some gutted. The observer samples lengths of the retained fish.

Total retained catch is calculated by a census of fish boxes and multiplying by the mean weight of an individual species commercial box. Total discards for the haul are estimated by the skipper taking into account the retained fish and the amount of the gear codend.

The crew fills one or more baskets of discards by collecting the species (all species of fish and invertebrates) before they would be dumped out to the sea by the conveyor belt. A sample of around 20 kg, depending of the size of discarded species, is collected. The discard sample is weighed by the observer using a balance.

All fish species of the discard sample are sorted and identified to species level or to genus-family level. All fish, and Nephrops crustacean, in the sample are measured for length (a subsample is made when there are large numbers of small species).

For mackerel, numbers at length were converted to age classes using ALK's obtained at the biological sampling programme (basis, half year) split in IXaN + VIIIc-West, VIIIc-East and VIIIab. For northern areas, ALK's from VIIIab were used

Results

During 2012 the discard sampling programme has covered more than 75% of the Spanish trawling fishing effort, except that exerted by the OTB_DEF_100_119_0_0 métier, to which the sampling programme covered only the 28% of the fleet effort, although the discard level for this metier is low. This metier is restricted to deeper water around the slope and the towing speed is slower and makes about 7 hour hauls (table 1).

Table 1a: Relative fishing effort in northern waters by metier and quarter exerted by the Spanish trawling fleets. Those quarters and divisions with white blue background were not covered by the discard sampling programme

OTB_DEF_100_119_0_0

Trips	1st Q	2nd Q	3rd Q	4th Q
Division VIa	2.0	11.6	1.8	0.3
Division VIb	0.0	0.0	0.5	0.0
Division VIIb	0.5	2.0	1.0	0.0
División VIIc	3.3	6.8	5.8	2.8
División VIIg	0.0	0.0	0.0	0.0
División VIIh	0.0	0.0	0.0	0.0
División VIIj	8.4	12.7	7.8	**14.7**
División VIIk	**6.6**	0.0	4.6	**6.8**

OTB_DEF_70_99_0_0

Trips	1st Q	2nd Q	3rd Q	4th Q
Division VIa	0.0	0.0	0.1	0.0
Division VIb	0.1	0.0	0.0	1.2
Division VIIb	0.7	0.4	0.1	3.2
División VIIc	2.1	2.1	1.9	**3.5**
División VIIg	**4.1**	**3.1**	1.4	2.3
División VIIh	**5.0**	**4.9**	2.8	**2.6**
División VIIj	**14.7**	**11.8**	**11.7**	**16.0**
División VIIk	0.8	1.3	1.1	**1.1**

Table 1b: Relative fishing effort in Iberian waters by metier and quarter exerted by the Spanish trawling fleets. Those quarters and divisions with white blue background were not covered by the discard sampling programme

OTB_DEF_>=55_0_0

Trips	1st Q	2nd Q	3rd Q	4th Q
VIIIc	**16.1**	**17.3**	**21.5**	**16.7**
IXa N	**7.8**	**5.9**	**6.2**	**8.5**

OTB_MPD_>=55_0_0

Trips	1st Q	2nd Q	3rd Q	4th Q
IXa N	**8.2**	**6.8**	**10.2**	6.8
VIIIc	**23.9**	**21.4**	**12.5**	**10.3**

PTB_MPD_>=55_0_0

Trips	1st Q	2nd Q	3rd Q	4th Q
VIIIc	**29.3**	**21.7**	**25.1**	**23.9**

OTB_DES_>=55_0_0

Trips	1st Q	2nd Q	3rd Q	4th Q
IXa S	**26.8**	**30.7**	**25.8**	**16.7**

PS_SPF_0_0_0

Trips	1st Q	2nd Q	3rd Q	4th Q
IXa S	10.3	33.5	45.7	10.5

In northern areas (Divisions VIa, VIb, VIIb, VIIc, VIIg, VIIh, VIIj and VIIk) a total of 339 hauls, corresponding to 11 trips, were sampled (93% for OTB_DEF_70_99_0_0) whilst 167 trips sampled in Iberian waters (VIIIc, IXaN and IXaS); in this case, roughly each trip correspond to a one working day (table 2)

Table 2a: Number of hauls sampled in northern waters by metier and quarter. Those quarters and divisions with white blue background denotes divisions and quarters with fishing activity not covered by the discard sampling programme

OTB_DEF_100_119_0_0

Hauls	1st Q	2nd Q	3rd Q	4th Q
Division VIa				
Division VIb	0	0		0
Division VIIb				0
División VIIc				
División VIIg	0	0	0	0
División VIIh	0	0	0	0
División VIIj				7
División VIIk	14	0		4

OTB_DEF_70_99_0_0

Hauls	1st Q	2nd Q	3rd Q	4th Q
Division VIa	0	0		0
Division VIb		0	0	
Division VIIb				0
División VIIc				6
División VIIg	5	18		
División VIIh	18	3		28
División VIIj	111	58	34	31
División VIIk				2

Table 2b: Number of trips (days) sampled in Iberian waters by metier and quarter. Those quarters and divisions with white blue background denotes divisions and quarters with fishing activity not covered by the discard sampling programme

OTB_DEF_>=55_0_0

Trips	1st Q	2nd Q	3rd Q	4th Q
VIIIc	10	13	14	9
IXa N	3	4	7	4

OTB_MPD_>=55_0_0

Trips	1st Q	2nd Q	3rd Q	4th Q
IXa N	2	2	1	
VIIIc	11	8	4	5

PTB_MPD_>=55_0_0

Trips	1st Q	2nd Q	3rd Q	4th Q
VIIIc	8	8	5	9

OTB_DES_>=55_0_0

Trips	1st Q	2nd Q	3rd Q	4th Q
IXa S	7	13	7	9

PS_SPF_0_0_0

Trips	1st Q	2nd Q	3rd Q	4th Q
IXa S		3	1	

In Iberian waters, the sampling effort matches quite well with the fishing effort (differences in relative effort were lower than a 9%), whilst in northern waters the first quarter of VIIj Division has been oversampled (16%) but the fourth quarter was undersampled by a 10%.

Mackerel discards in 2012

An estimation of 3.811,4 mt of mackerel were discarded during 2012 in northern waters, most of them during the first quarter (77%). 91.3% of the mackerel discarded was located in VIIj. In northern Spanish waters (VIIIc and IXaN) a total of 2.209,2 mt were discarded, (99% in VIIIc) as in the case of northern areas 83,3% were taken during the first quarter. Complementary, in IXaS discards mainly occurred during the second half of the year (81% of a total of 870 mt), most of them specifically during the third quarter (64%) (table 3).

Table 3: Mackerel discard estimates by ICES divisions and quarter in metric tonnes (sampled discards raised to the total fishing effort)

Quarter	Via	Vib	VIIb	VIIc	VIIg	VIIh	VIIj	VIIk	VIIIc	IXaN	IXaS
1 st	na	Esf. 0	na	0.8	21.7	289.8	2609.1	0.0	1820.2	21.7	26.4
2 nd	na	Esf. 0	na	1.6	0.0	14.4	735.3	0.0	64.9	0.0	135.9
3 rd	na	na	na	1.4	0.0	0.0	68.0	0.0	279.3	0.0	553.3
4 th	na	na	Esf. 0	0.6	0.0	0.0	68.8	0.0	23.1	0.0	153.9
Total	**na**	**na**	**na**	**4.4**	**21.7**	**304.2**	**3481.2**	**0.0**	**2187.5**	**21.7**	**869.5**

Discard estimates by age group in northern areas:

Discards by age group are shown in figure 1

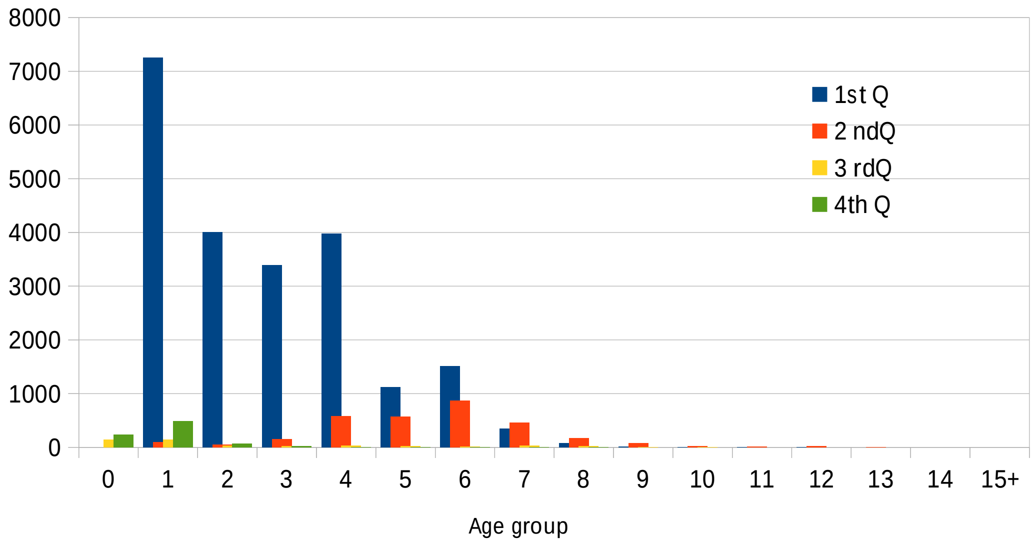

Figure 1: Discard estimates (thousands) by age group and quarter in northern waters (VI and VII divisions) in 2012.

Most of the discards occurred during the first quarter, mainly composed by young fish (mean length of 26.9); this pattern is different to that found in the second quarter in which adult fish are mainly discarded (age groups 4 to 9 and mean length of 34.6 cm). During the second half of the year, discards are negligible, and most of them came from younger fish (75% belonging to age groups 0 to 3). Comparing with results achieved by the Dutch fleet (Borges et al., 2008), Spanish discards could have higher size than those of the Dutch freezer-trawler fleet.

Discard estimates by age group in north Iberian Peninsula (VIIIc and IXaN):

Discards by age group in VIIIc are shown in figure 2

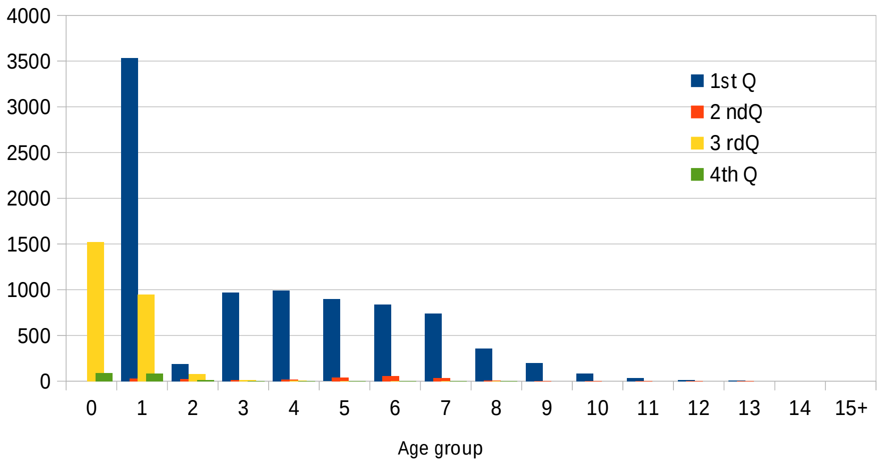

Figure 2: Discard estimates (thousands) by age group and quarter inVIIIc Division in 2012.

Most of the discards occurred during de first quarter (75%), mainly composed by young fish (53% belonging to age group 3 or younger). Besides, during the third quarter the number of discards increased being almost all of them for ages groups 0 and 1. During the second and fourth quarter discards were almost negligible. Comparing the relative age composition in both discards and landings, the differences in age distribution are significant (maximum difference in cumulative relative age distribution was 0.51, higher than the Kolmogorov-Smirnoff statistic), but landings and catch are almost the same age frequency distribution (maximum difference in cumulative relative age distribution was 0.07, lower than the Kolmogorov-Smirnoff statistic)

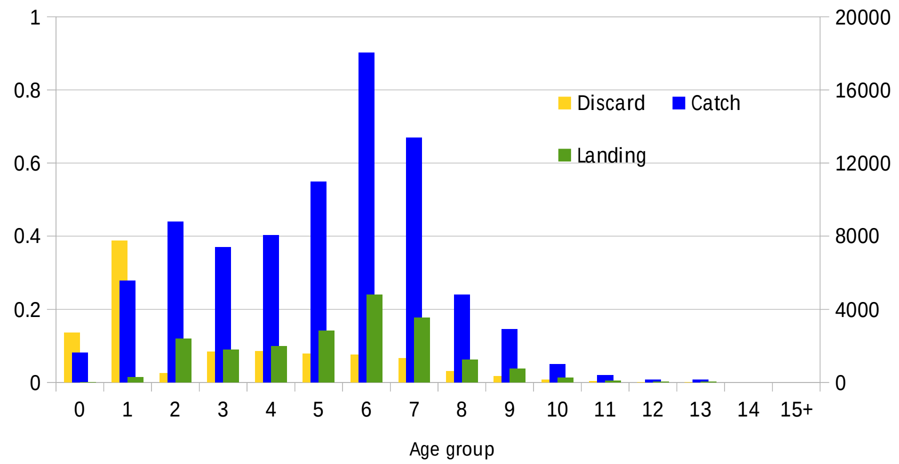

Figure 3: Relative comparison between year landing and discard (main Y axis) and catch in number (secondary Y axis, number in thousands) in VIIIc Division in 2012.

Discard by age group in IXaN are shown in figure 4

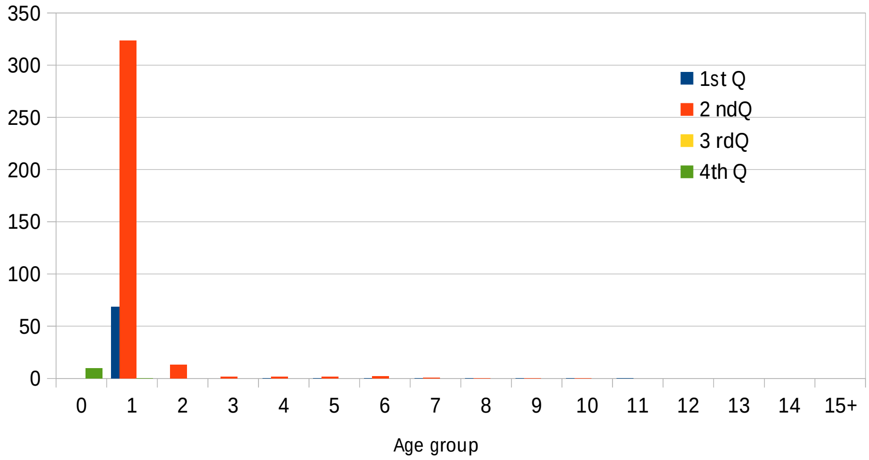

Figure 4: Discard estimates (thousands) by age group and quarter in IXaN Division in 2012.

Contrary to that observed in VIIIc, in IXaN most of the discard took place during the second quarter and during the third one, no discard was estimated. Moreover, only juveniles (age group 1 during the first and second quarter and age group 0 during the fourth) were discarded. Also the differences between age composition in discard and landing are much higher than that observed in VIIIc, and this resulted also in significant differences in age distribution between catch and landing (maximum difference in cumulative relative age distribution were 0.70 and 0.93 for, respectively, landing and discard comparison and catch and landing)

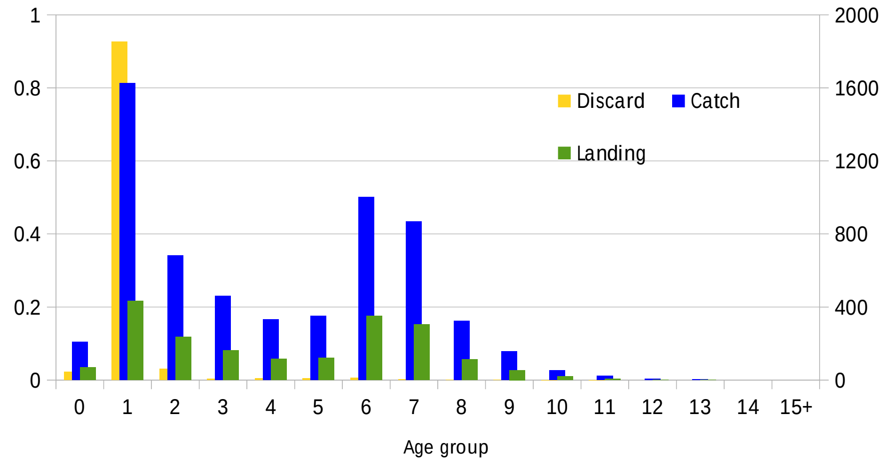

Figure 5: Relative comparison between year landing and discard (main Y axis) and catch in number (secondary Y axis, number in thousands) in IXaN Division in 2012.

In north Spain (VIIIc and IXaN), discards represent less than a 10% of the total catch. There was almost no discards during second half of the year (figure 6ab).

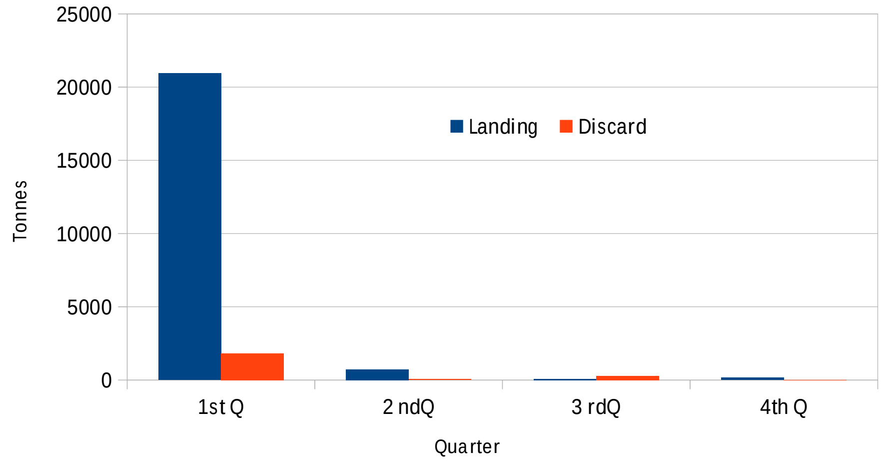

Figure 6a: Discard and landing estimates (tonnes) by quarter in VIIIc Division in 2012.

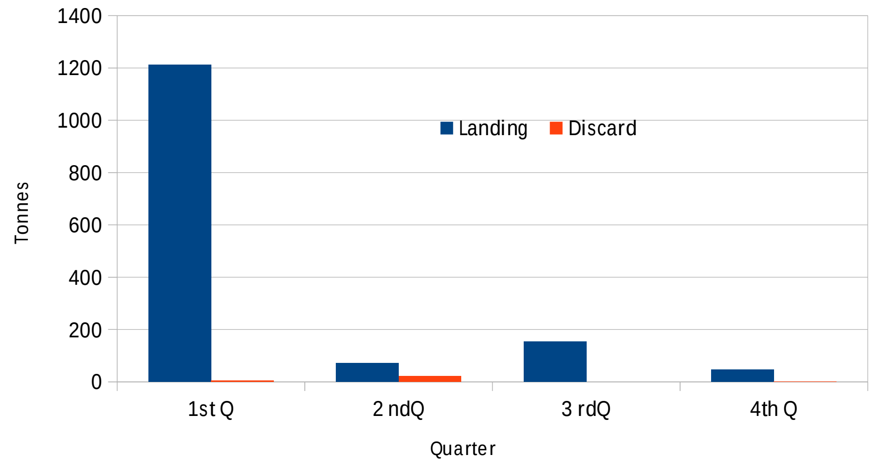

Figure 6b: Discard and landing estimates (tonnes) by quarter in IXaN Division in 2012.

<u>Discard estimates by age group in south Iberian Peninsula (IXaS):</u>

Due to difficult in ALK, discard estimates by age group in south Iberian Peninsula (IXaS) was not available.

As expected, discards in the Gulf of Cadiz are relatively important and much higher than landing (a 67% of the total catch) and most of them occurred during the second half of the year (figure 7)

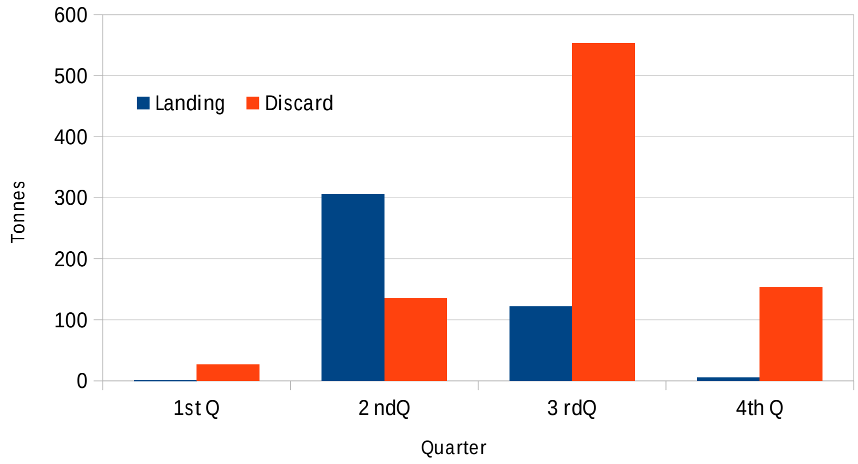

Figure 7: Discard and landing estimates (tonnes) by quarter in IXaS Division in 2012.

Discard time series

The time series analysed in this document started in 2003. (figure 8). Discarded mackerel in the analysed regions didn't show a defined trend, alternating years with highest discarded values in northern with other in which the bulk of discarded mackerel occurred in north Iberian waters.

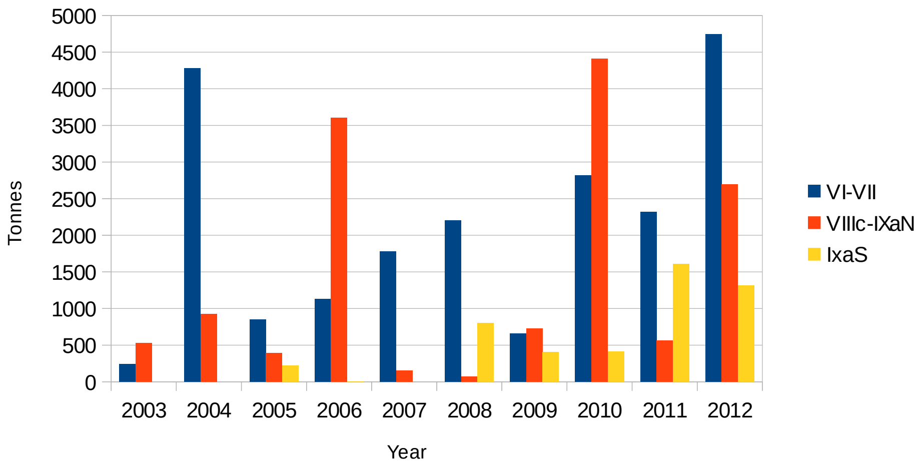

Figure 8: Discard estimates (tonnes) by year and Division since 2003.

Most of the discard in northern area (VI and VII) were taken by the metier targeting in megrim (OTB_DEF_70-99_0_0); only in 2011 discard for metier targeting in hake and monkfish (OTB_DEF_100-119_0_0) were relevant as shown in figure 9

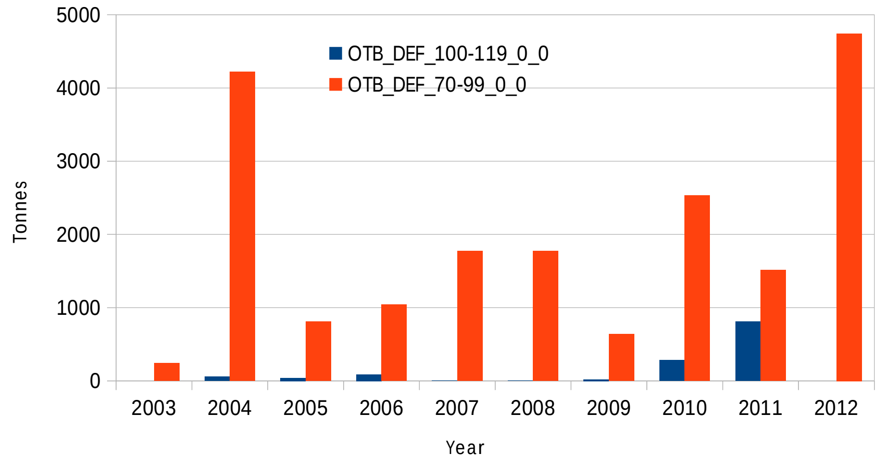

Figure 9: Discard by metier and year in northern area (Divisions VI and VII)

Age composition along time series did not show any particular pattern, but in weight, most of them are composed by adult fish except the proportion occurred in 2006, 2008 and 2011 (figure 10)

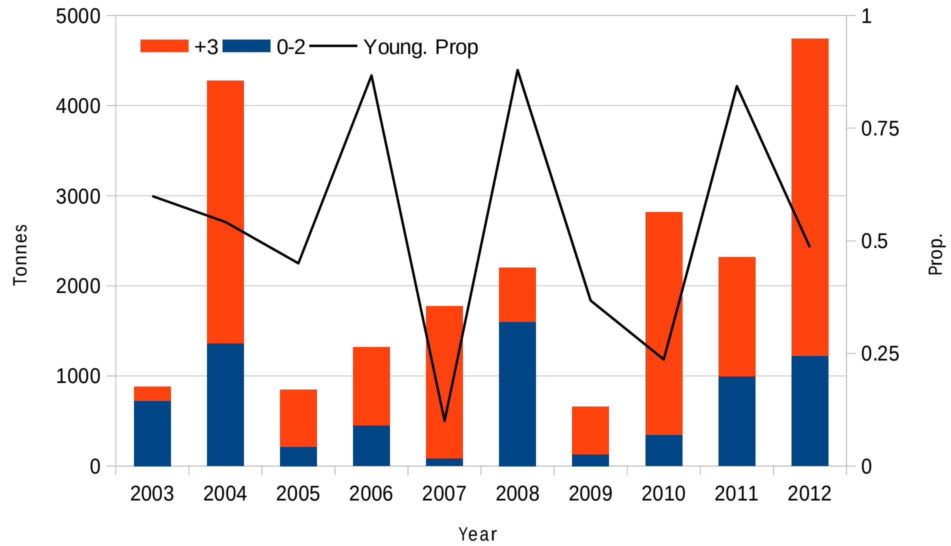

Figure 10: Discard proportion (tonnes) between younger mackerel (0-2 age groups) and adults (+3) since 2003. Right Y axis shows the proportion in number of younger mackerel (Divisions VI and VII)

In north Iberian Peninsula, there was a change in 2006 when the metier targeting in mixed pelagic and demersal species, took more discard than that of the targeting in demersal species one (figure 11).

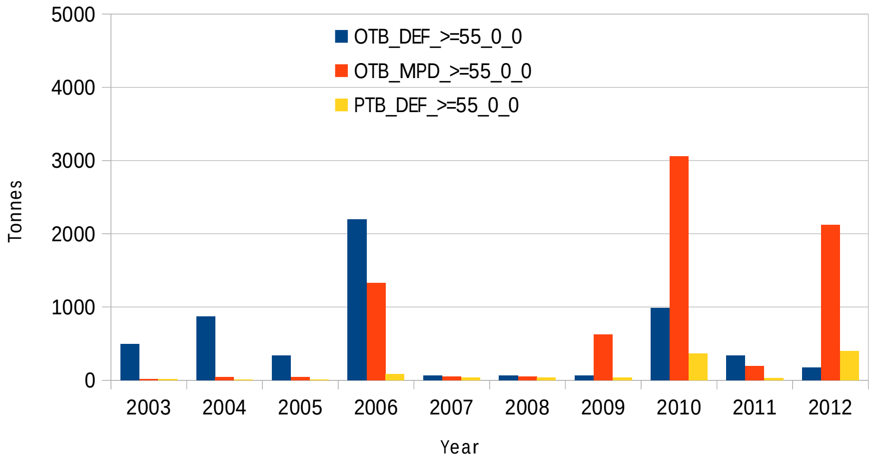

Figure 11: Discard by metier and year in north Iberian Peninsula (Divisions VIIIc and IXaN)

In this case, most of the mackerel discard belonged to age group 2 and younger (figure 12), achieving up to 99%.

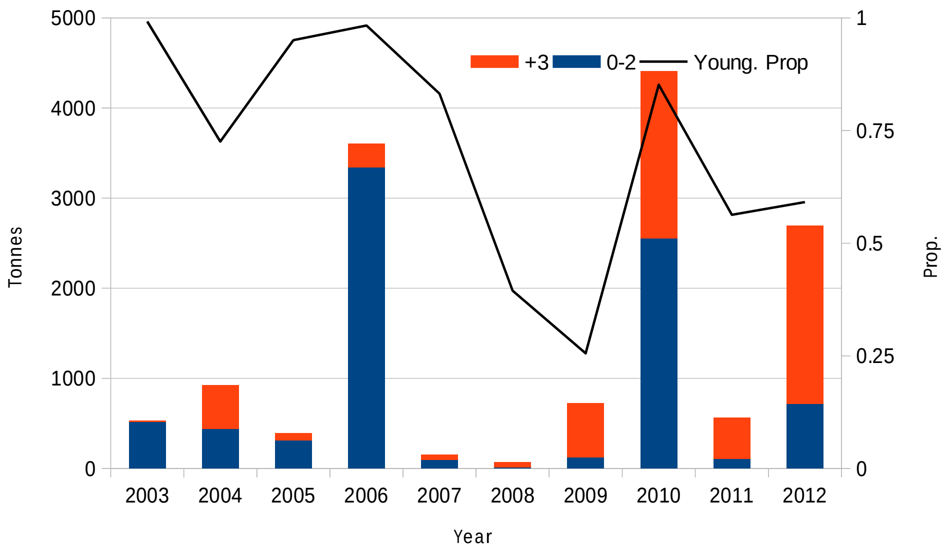

Figure 12: Discard proportion (tonnes) between younger mackerel (0-2 age groups) and adults (+3) since 2003. Right Y axis shows the proportion in number of younger mackerel (Divisions VIIIc and IXaN)

In the Gulf of Cadiz, purse seiner métier was also analysed, and most of the discard were taken by this métier, as shown in figure 13

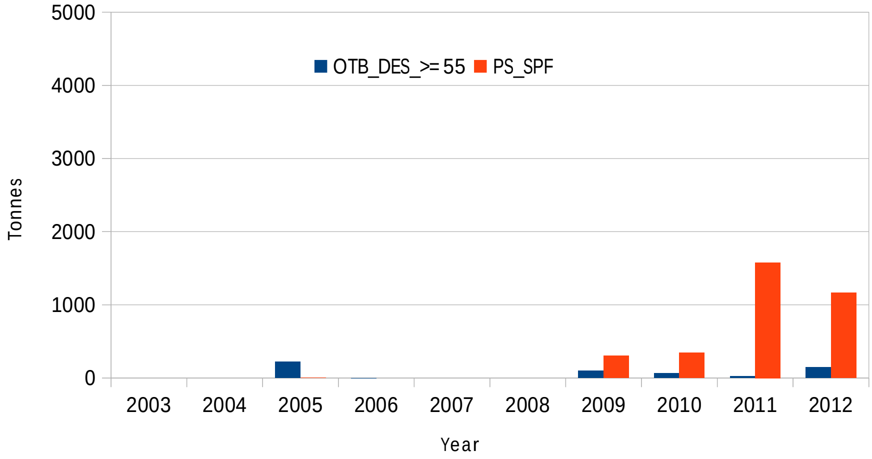

Figure 13: Discard by metier and year in south Iberian Peninsula (Division IXaS)

Precision

CV's by half year and metier are shown in figure 14a-d. These were calculated for mackerel discards in number. No clear relation between sampling effort (no of trips) and cv's could be inferred since precision is calculated on species basis, thus depending on other factors such as relative abundance (compared with the target fishing species), mackerel size (i.e. recruitment strength) among other factors, but in general these are similar to that calculated for the Dutch pelagic freeze-trawler fleet between 2002 and 2005. (82.1 in number and 39.1 in biomass, Borges et al, 2008).

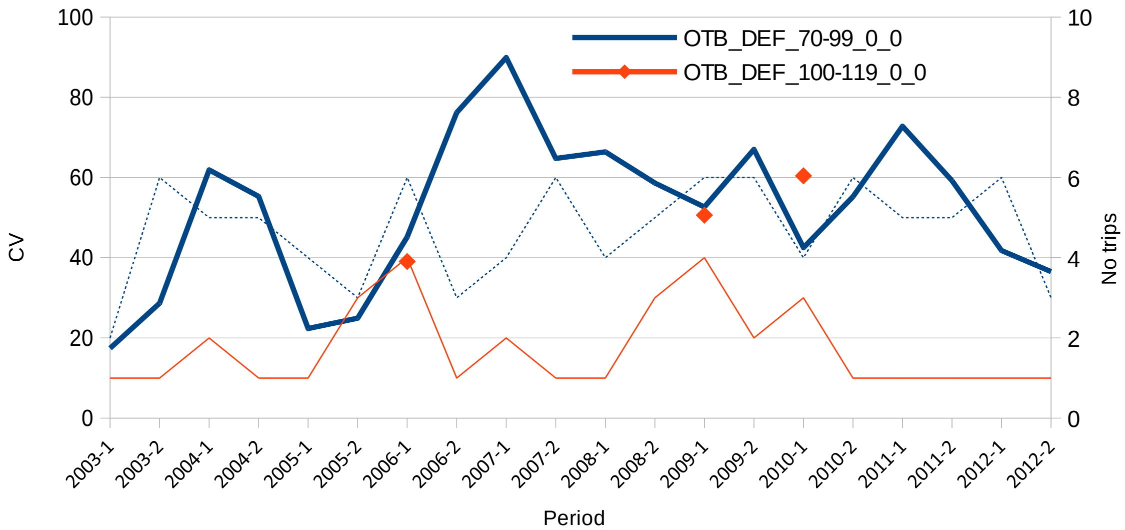

Figure 14a: CV (left axis, thick line) and number of trips sampled (right axis, dashed line) by metier and half year in northern area (Divisions VI and VII)

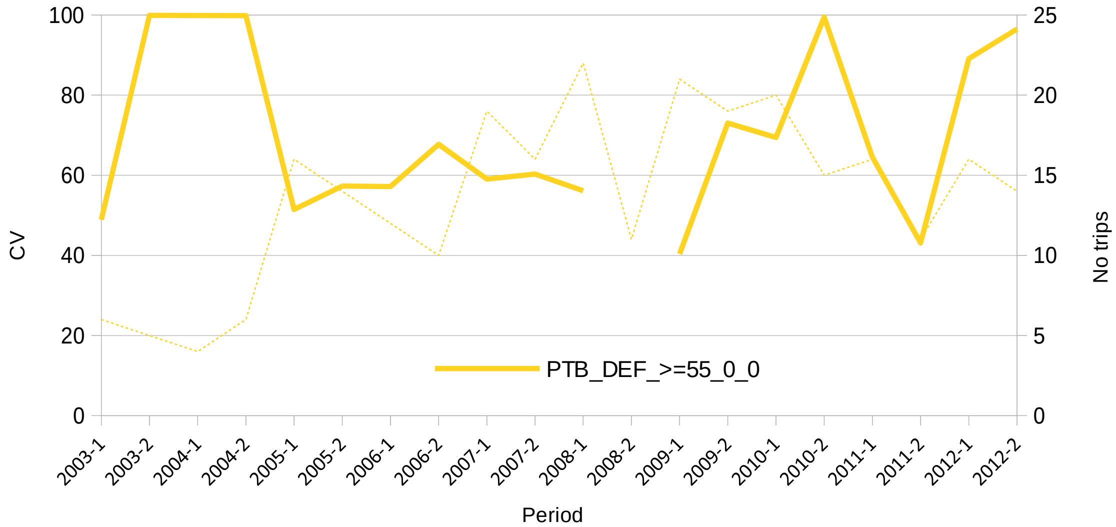

Figure 14b: CV (left axis, thick line) and number of trips sampled (right axis, dashed line) by metier and half year in north Iberian Peninsula (Divisions VIIIc and IXaN)

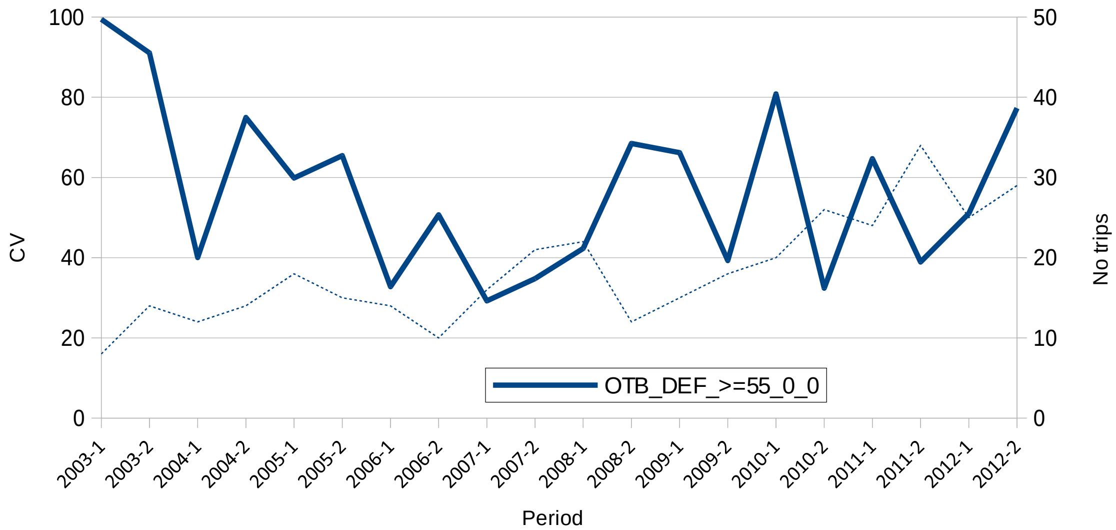

Figure 14c: CV (left axis, thick line) and number of trips sampled (right axis, dashed line) by metier and half year in north Iberian Peninsula (Divisions VIIIc and IXaN)

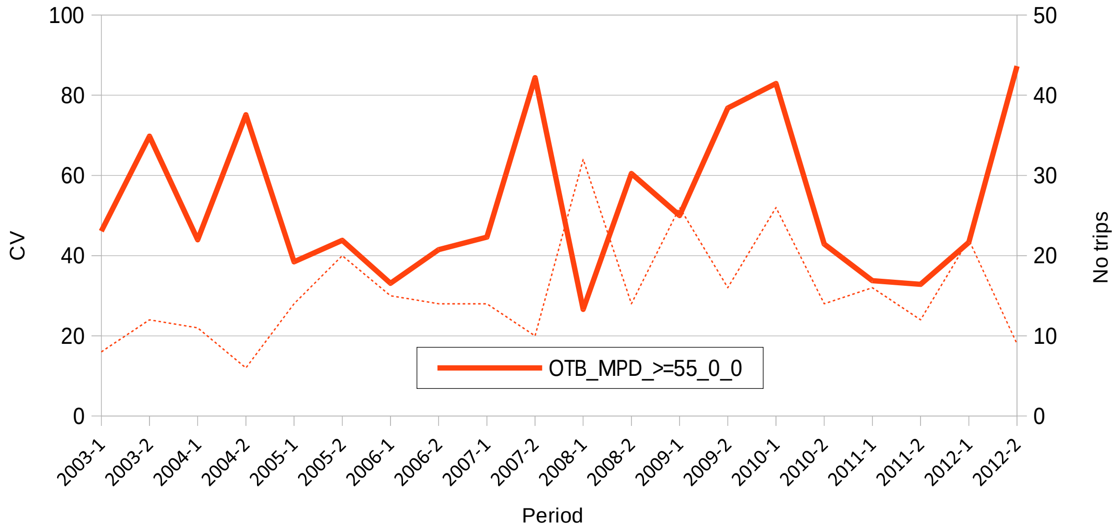

Figure 14c: CV (left axis, thick line) and number of trips sampled (right axis, dashed line) by metier and half year in north Iberian Peninsula (Divisions VIIIc and IXaN)

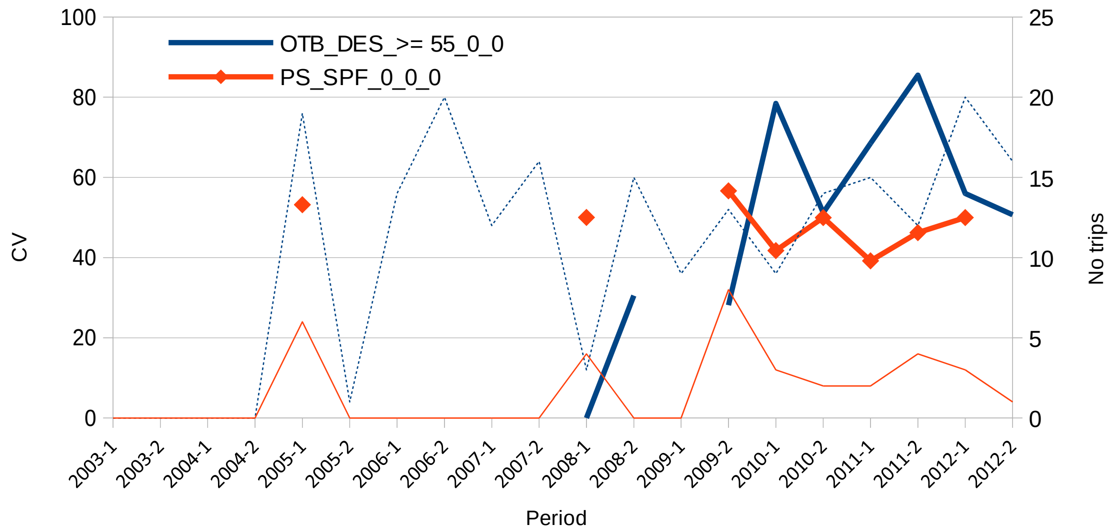

Figure 14d: CV (left axis, thick line) and number of trips sampled (right axis, dashed line) by metier and half year in south Iberian Peninsula (Gulf of Cadiz, Division IXaS)

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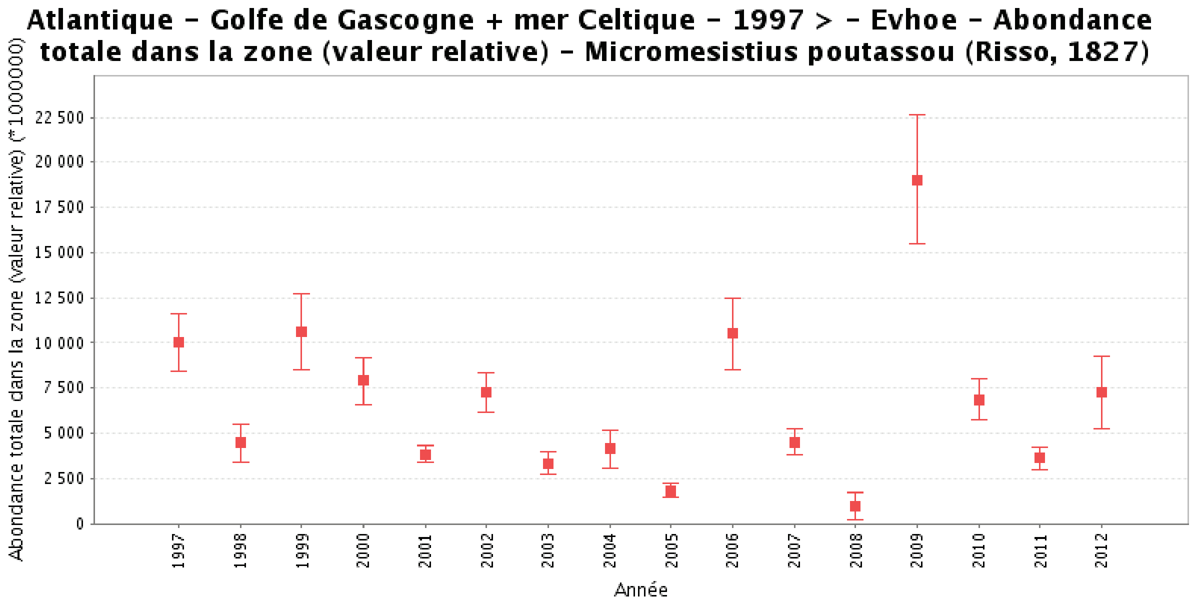
Blue Whiting : EVHOE indices

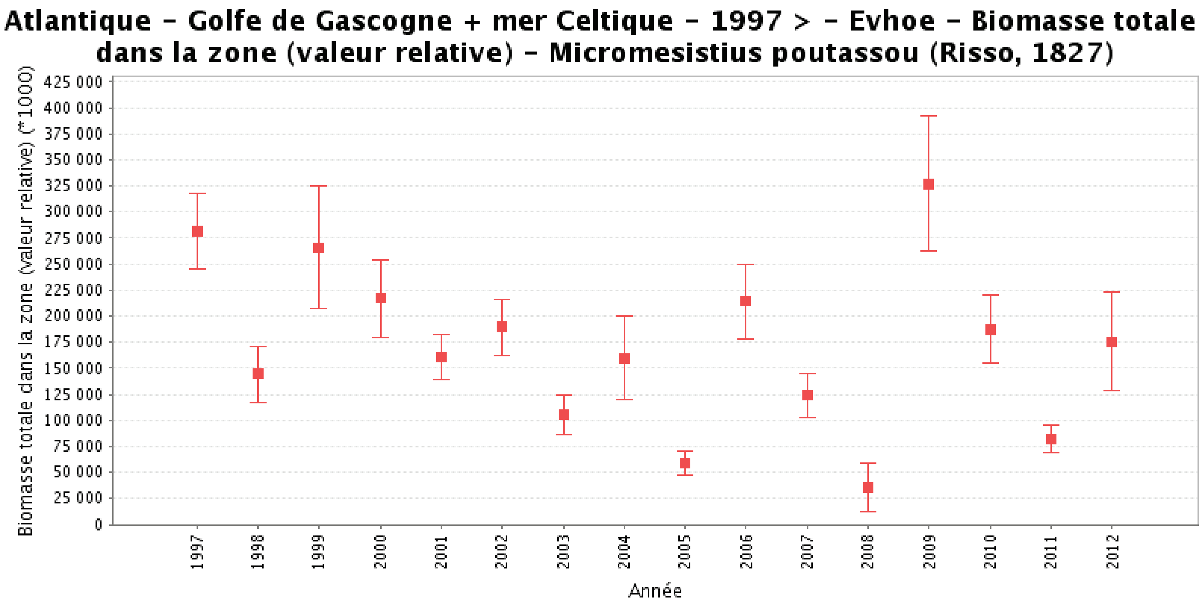
WD for WGWIDE – July 2013

1. Celtic Sea and Bay of Biscay combined

Abundance index :



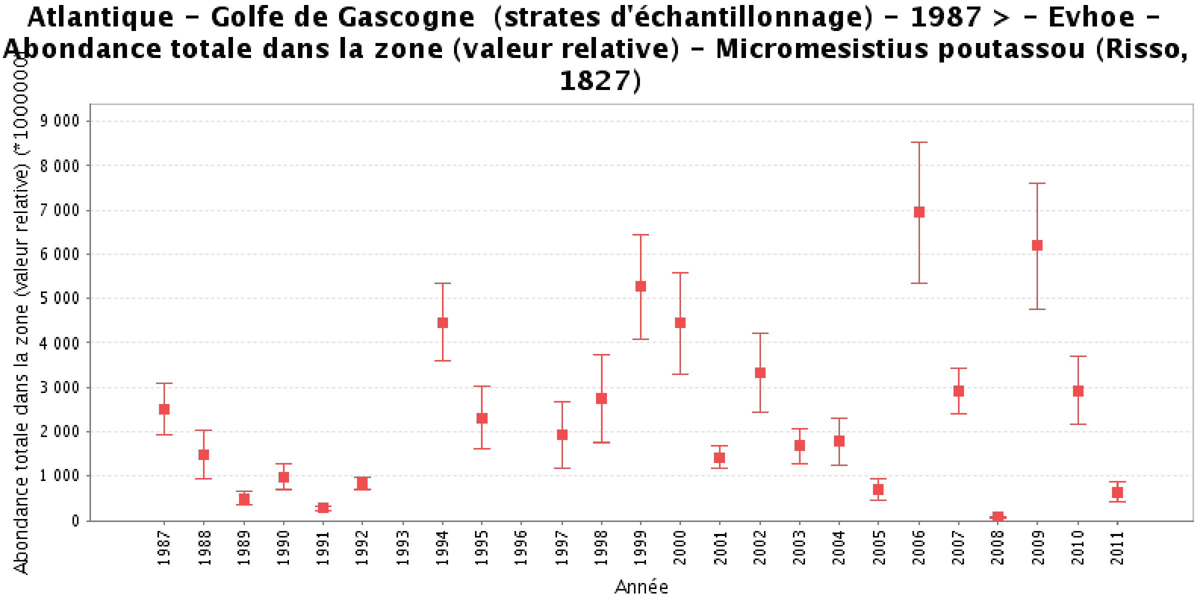
Biomass index :



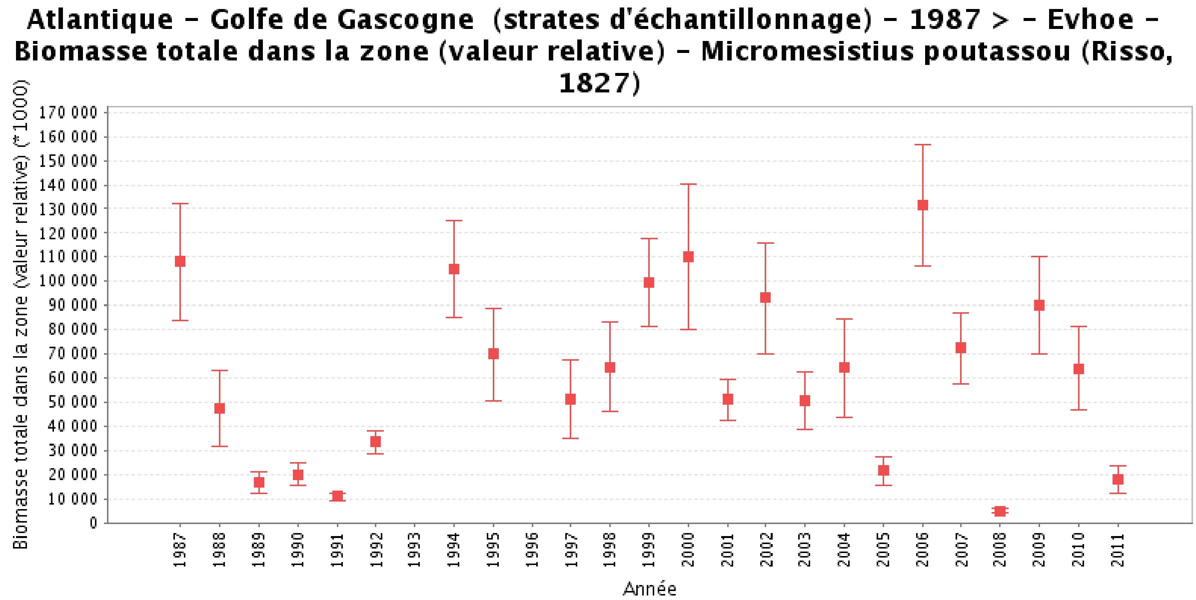
Ifremer

2. Bay of Biscay only **(2012 missing)**

Abundance index :



Biomass index :



Working Document to WGWIDE, Copenhagen, 27 August-2 September 2013

Changes of some biological traits of the southern component of the NEA Mackerel (*Scomber scombrus*), 1990-2012: mean length and mean weight-at-age, length-weight relationships and condition.

By

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Abstract

Northeast Atlantic Mackerel (*Scomber scombrus*) perform extensive migration between spawning, feeding and over-wintering areas. During the last decade, there are evidences of changes in the population behavior, affecting, among others, the recruitment variability, the distribution and migration and even the spawning time.

Southern component of the Northeast Atlantic mackerel population migrates towards the southern spawning area (Cantabrian Sea) at the end of winter. An analysis of the fishery indicates a forward shift in the timing of the migration since 2000. Such a shift causes that spawning in the Southern component has occurred earlier in the last decade compared to the previous. Other variables as changes on the structure of the population may be also associated to these changes in the migratory pattern and therefore could have effects on biological parameters of this species. This work analyses some biological traits and its inter-annual variations of the mackerel southern component during the period 1990-2012. We explore evolution of mean length and weight-at-age, length-weight relationships and condition factor. Mean length and weights-at-age showed significant annual differences in the Southern component of the NEA Mackerel in the spawning season during 1990-2012. Annual changes in mean length and weight at age were observed. During the last decade there was a decrease in mean weight at age in age group 4 and older. The same trend was also observed in gutted weights since 2000 and in the mean weight of the gonads in the active maturity stages. Finally, some explanations about the causes of these changes are achieved and also we analyze the management implications.

Introduction

Mackerel (*Scomber scombrus,* L 1754) is an abundant migratory pelagic fish in the north-east Atlantic where it plays an important ecological role (ICES, 2012). The stock maintains an important fishery (annual landings of between 500 and 1000 thousand tonnes) consisting in several local fleets and a large pelagic fleet across its range of distribution, whose activity also follows a sequential timing coupled to the feeding-spawning migration along the European shelf (ICES, 2012). Therefore, understanding how changes in environmental conditions may affect its life history characteristics becomes important for both biological and management purposes.

North East Atlantic Mackerel (NEA) distribution extends from the Iberian Peninsula in the south to the Northern Norwegian Sea in the north, and Iceland in the west to western Baltic Sea in east. Even though spawning occurs on the shelf from south of Iberian Peninsula to the Norwegian Sea, there are two loci of increased intensity. One area located along the shelf break from Spanish waters in March-April (Sola et al., 1990, Costas et al., 2000), and the other, around Ireland to the west of Scotland where spawning peaks in June (Beare and Reid 2002 ; Iversen 2002). Together with these, there is another area located the central North Sea with peak spawning in May-July. For management purposes, NEA mackerel is considered to be a single stock but with three spawning components (Southern, Western and North Sea) (ICES, 1996).

Mackerel performs extensive migration between spawning, feeding and over-wintering areas. Tagging experiments have demonstrated that, after spawning, fish from Southern and Western areas undertake a feeding migration to both the Norwegian and North Sea (Uriarte et al., 2001). After overwintering around north Scotia and North Sea, a southwards spawning migration to the Cantabrian Sea takes place. (ICES, 2010).

In recent years the NEA mackerel stock has shown changes in both the timing and extension of these migrations, which in turn have affected the activity of different fleets along the European shelf, tightly coupled with this migration behaviour (ICES, 2012). Besides, an increase in the recruitment variability, changes in the distribution and migration and even variation in spawning time (ICES, 2012) have been also observed.

In the south, mackerel has been found to migrate progressively earlier (by ~30 days in a decade) to the southern spawning area in the Cantabrian Sea (Punzón and Villamor, 2009). The analysis of individual reproductive parameters and other indirect indicators of spawning activity (i.e. egg abundance in the plankton) confirm that this earlier migration to the southern spawning ground reflects a concomitant earlier spawning activity (Villamor et al. 2011).

The reasons for all these changes have been widely discussed, but are poorly understood (ICES, 2012), although it has been proposed that, given the generally warming trend in the ocean, temperature and density-dependent expansion could be potential causal effects, together with food abundance and size distribution changes.

These changes in distribution of mackerel could impact on the structure of the population and therefore could have effects on biological parameters of this species.

To determine whether the changes are affected biological parameter, in this paper we analyze the IEO database of mackerel biological parameters from 1990 to 2012 (i.e. mean length and weight-at-age and length / weight relationship, maturity stages, gutted and gonads weights)

Materials and Methods

We analyzed biological samples from 1990 to 2012 taken in Divisions VIIIc and IXa North. Monthly samples (by 100 fish each) were selected at random from the commercial catches. In addition, samples were taken using pelagic mid-water trawl during the annual acoustic survey in that area (PELACUS surveys). The data analyzed in this study refers to samplings gathered from the main spawning area (Division VIIIc) during the spawning season (January-June). The commercial fleet and acoustic survey data were analyzed separately.

A total of 35,527 specimens (12,796 from the commercial fleet and 19,731 from acoustic survey) were analyzed. For each individual, the following variables were recorded: total body length (TL, cm), total body weight (TW, g); their sex and maturity stages were determined by macroscopic examination of the gonads following Walsh et al. (1990) scale, and *sagitta* otoliths removed. Gonads were dissected and weighed (GoW) from years 1998, 2005, 2007, 2010-2012, and gutted weight (GuW) was recorded from years 2004-2007 and 2010-2012. All weight recorded with 0.001 g accuracy. Age was estimated by interpreting and counting growth rings on the otoliths. Methodological ageing procedures described in ICES (1995 and 2010) were followed.

Mean lengths-at-age; mean weight (TW and GuW)-at-age and the corresponding standard deviations were calculated by year and by year-class. Also, mean gonad weight by maturity and mean weight (TW and GuW) by maturity stage were calculated.

Length (TL, 1 cm length class)-weight (TW, g) relationship was estimated for each year. *Inbio* package in R (Sampedro et al., 2005), was used to estimate de coefficient of variation for parameters a and b of the relationship. Also a logarithmic transformation was used to express these relationships, using a linear regression. Regression slopes were compared by analyses of variance (ANOVA).

Relative condition and relative weight were estimated as described in Froese (2006) to discuss variations in the length-weight relationships. Before estimating the relative condition and relative weight, we performed a regression analysis of *log a* over *b* to identify outliers in the length-weight relationships (Froese, 2000). The strong interrelationship between parameters *a* and *b* is linearized and helps in detecting length-weight relationships that are questionable (outliers), such small size range, few data with high variance, or outliers in the respective sample (Froose, 2006). Mean condition factors from weight-length relationships were calculated as $K_{mean}=100aL^{b-3}$. Relative weight $W_{rm}=100W/(a_m L^{bm})$ was used for comparing the condition of individuals across populations, were a_m is the geometric mean of *a* and b_m is the mean of *b* across all available non-questionable weight-length relationships estimates for mackerel. Estimation of relative weight as percentage of mean weight derived from a mean weight-length relationship for mackerel.

We have also analyzed the mean weight at age in the stock for southern mackerel component during 1990-2011 presented to the WGWIDE (2012). In the southern area mean weight at age in the catch is based on Spanish sampling (IEO and AZTI sampling) taken during the first half of the year in Division VIIIc (Sub-division VIIIc West+ Sub-division VIIIc East) is taken as the mean weights at age in the stock (Eltink et al, 2002).

Results

Mean weights at age in the stock for the southern mackerel component during 1990-2011.

Figure 1 shows the mean weight at age in the catch during the first half of the year in Division VIIIc (1990-2011 time series). A decreasing trend in mean weight at age for age group 2 and older was observed .From age 3 to age 11 the relationship is significant (p=0.000).

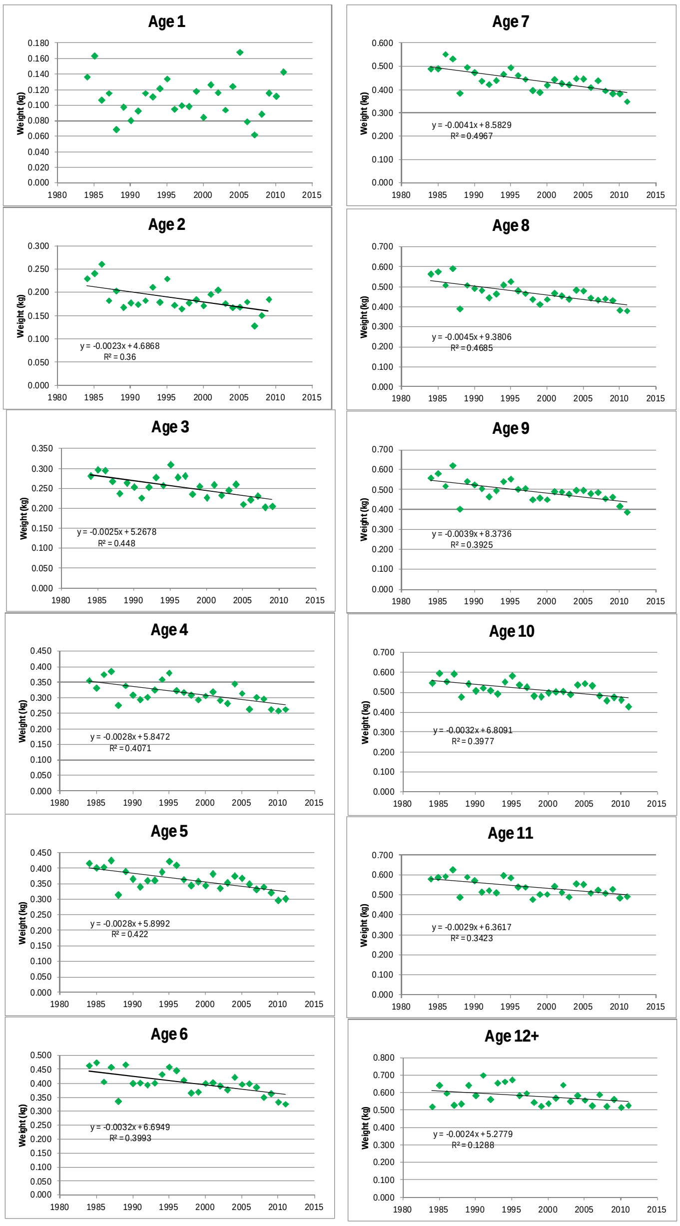

Figure 1. Mean weights (k) at age in the stock for the southern mackerel component during 1990-2011.

There were significant differences in mean weight at age between year classes. A decreasing trend in the stock mean weight at age was observed for ages 3-8, 4-11 and 7-11, and the relationship of all of them was highly significant (p=0.000). For ages 1 and 2 such decrease was not observed nor significant relationships (p= 0.804 for age 1; p= 0.013 for age 2) (Figure 2). The lowest mean weight at age 1 were those of the 1987, 2005 and 2006 year classes, and for age 2 was 2005 year class. The highest values for age 1 were those of the 1984 and 2004 year classes, and for age 2 was also 1984 year class. The 2002 year class achieved the lowest weight at age for ages 3 to 8. In the overall mean weight at age (ages 1-11) the observed decreasing trend highly significant (p=0.000).

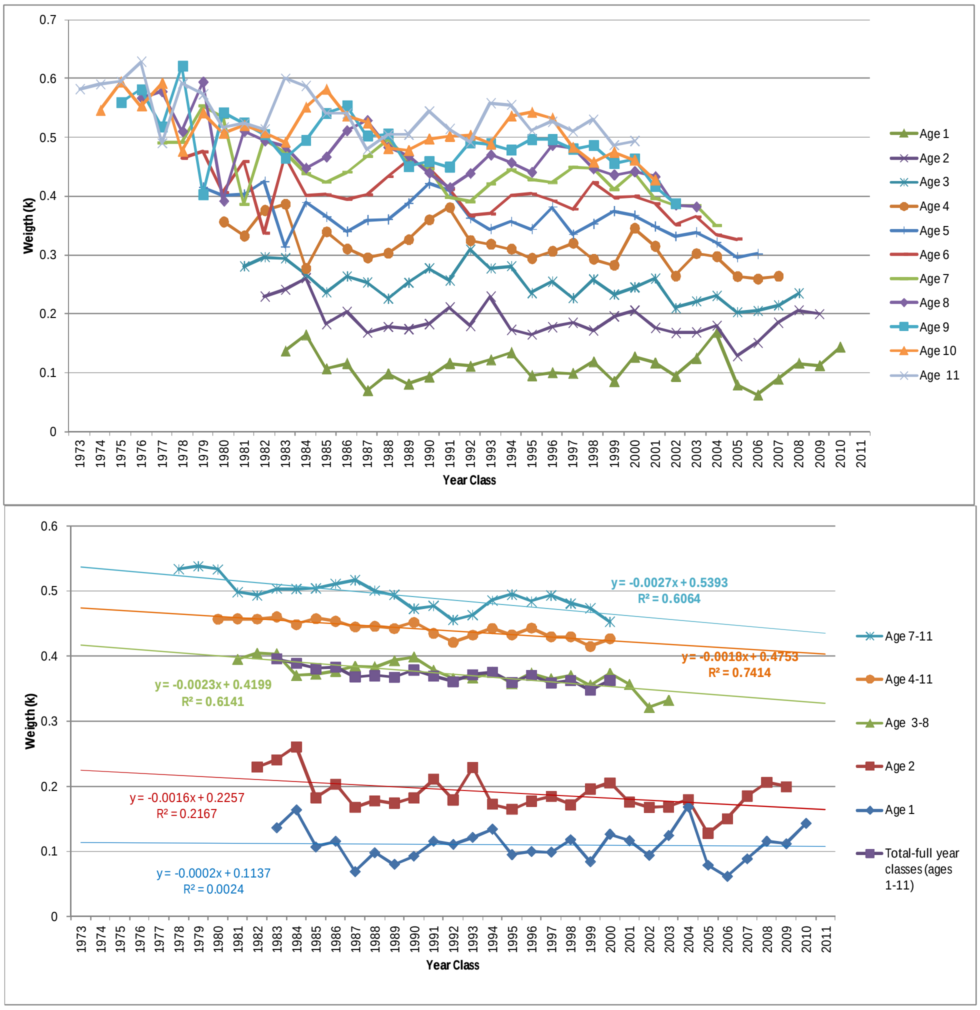

Figure 2. Mean Weight (k) at age in the stock for the southern mackerel, by year class and age.

Mean length-at-age, mean weight (TW)-at-age, mean gutted weight (GuW)-at-age and mean gonad weight (GoW) by year (1990-2012), from commercial fleet and acoustic survey sampling.

Figure 3 shows the mean length at age for mackerel from commercial fleet and acoustic survey (PELACUS). Although there is no clear trend, a significant decreasing trend in size especially for ages 4 to 7 ($p<0.05$) is observed from the mid-2000s (mainly since 2008) from commercial fleet sampling, although no trend was observed for ages 1 to 3 and 9 to10 nor from the PELACUS survey data.

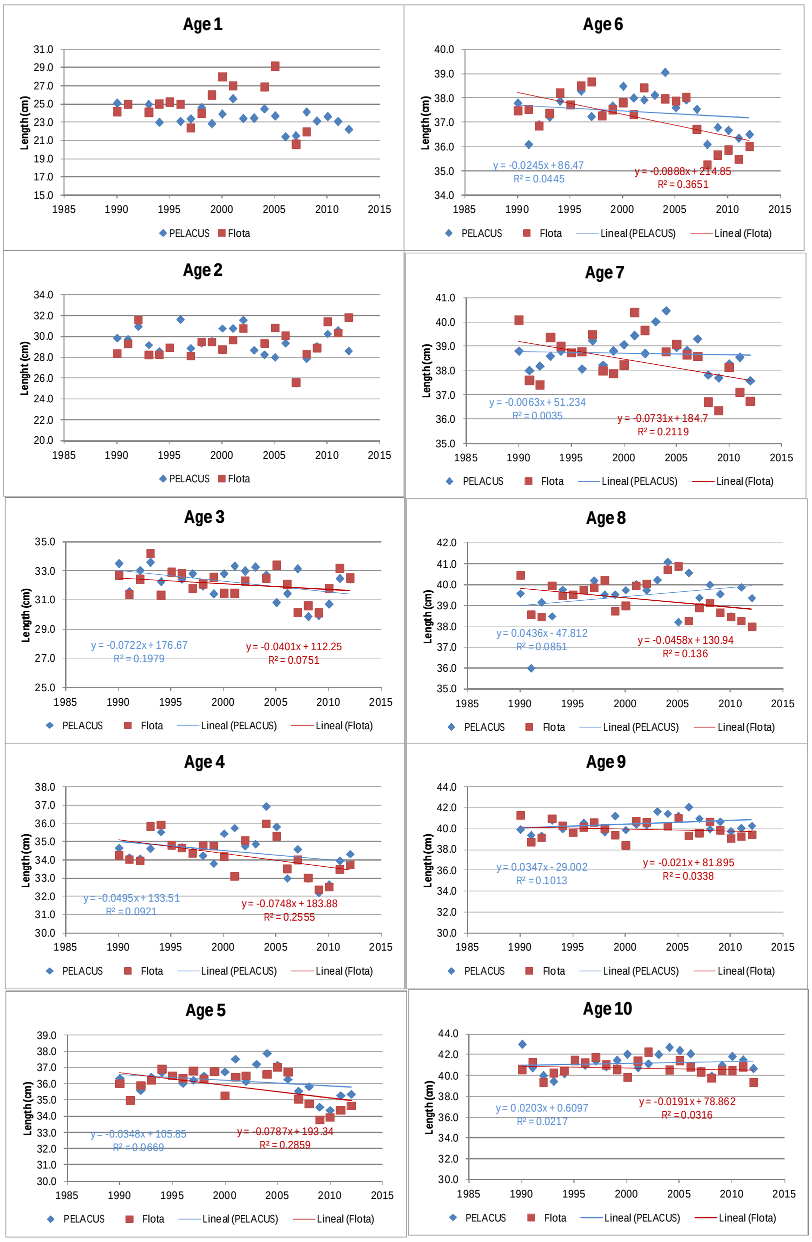

Figure 3. Mean length (cm) at age from the commercial fleet and acoustic survey (PELACUS) sampling for the period 1990-2012.

Figure 4 shows the mean weight **(TW)** at age by year for mackerel during 1990-2012. A decreasing trend is observed for ages 4 and older from de commercial fleet ($p<0.05$) and for age 3+ from acoustic survey ($p<0.05$). On the contrary, no differences has been found for ages 1 and 2.

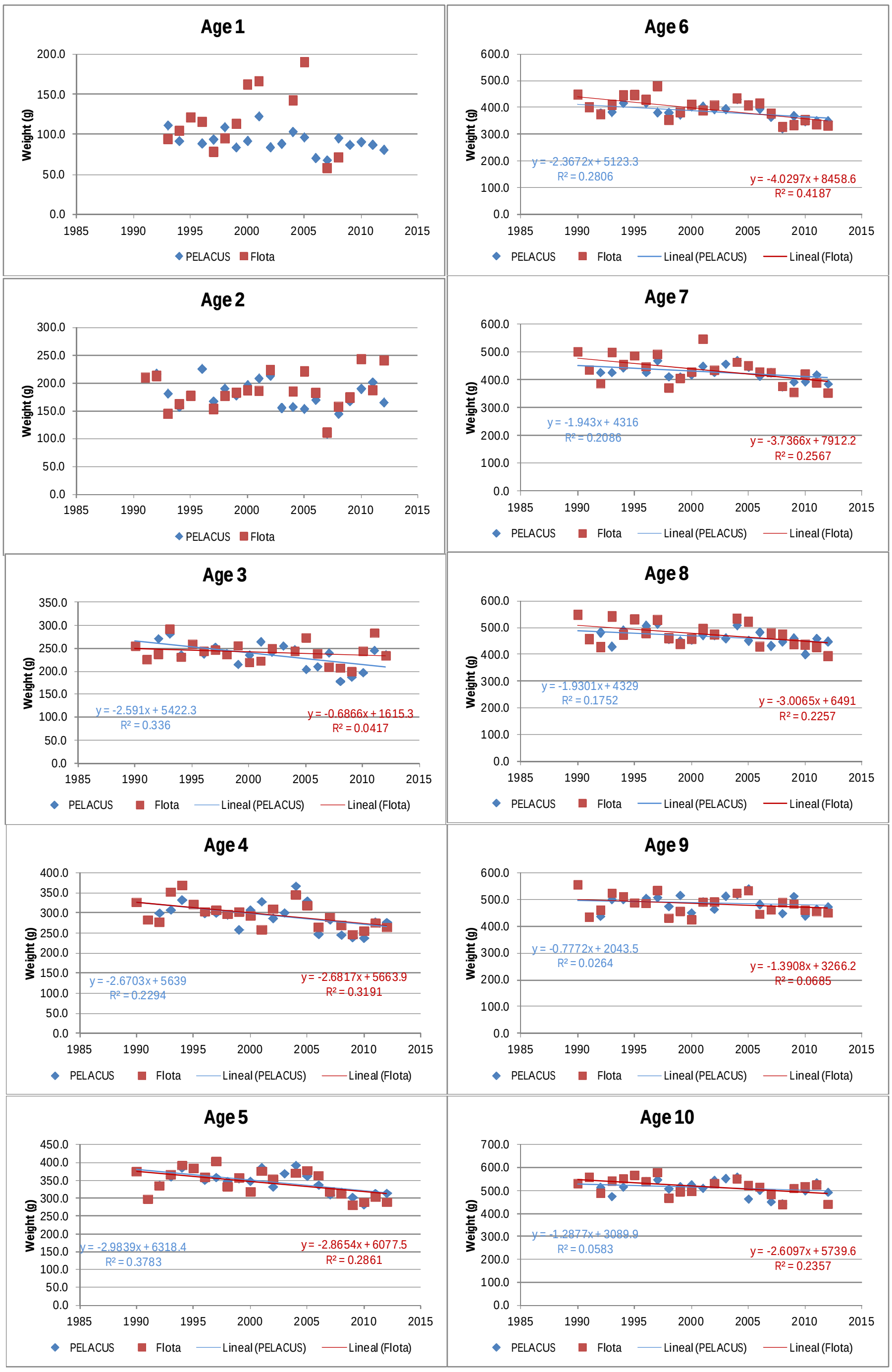

Figure 4. Mean weight (TW, g) at age by year from the commercial fleet acoustic survey (PELACUS) sampling for the period 1990-2012.

Figure 5 shows the mean gutted weight **(GuW)-**at-age by year for mackerel for 2004-2006 and 2010-2012 from commercial fleet sampling (no data from acoustic survey). The decreasing trend is clearer than for the total weight. There are significant differences from age 4 to age 10 ($p<0.05$), again no decrease trend was observed in young fish (age 2 and 3)

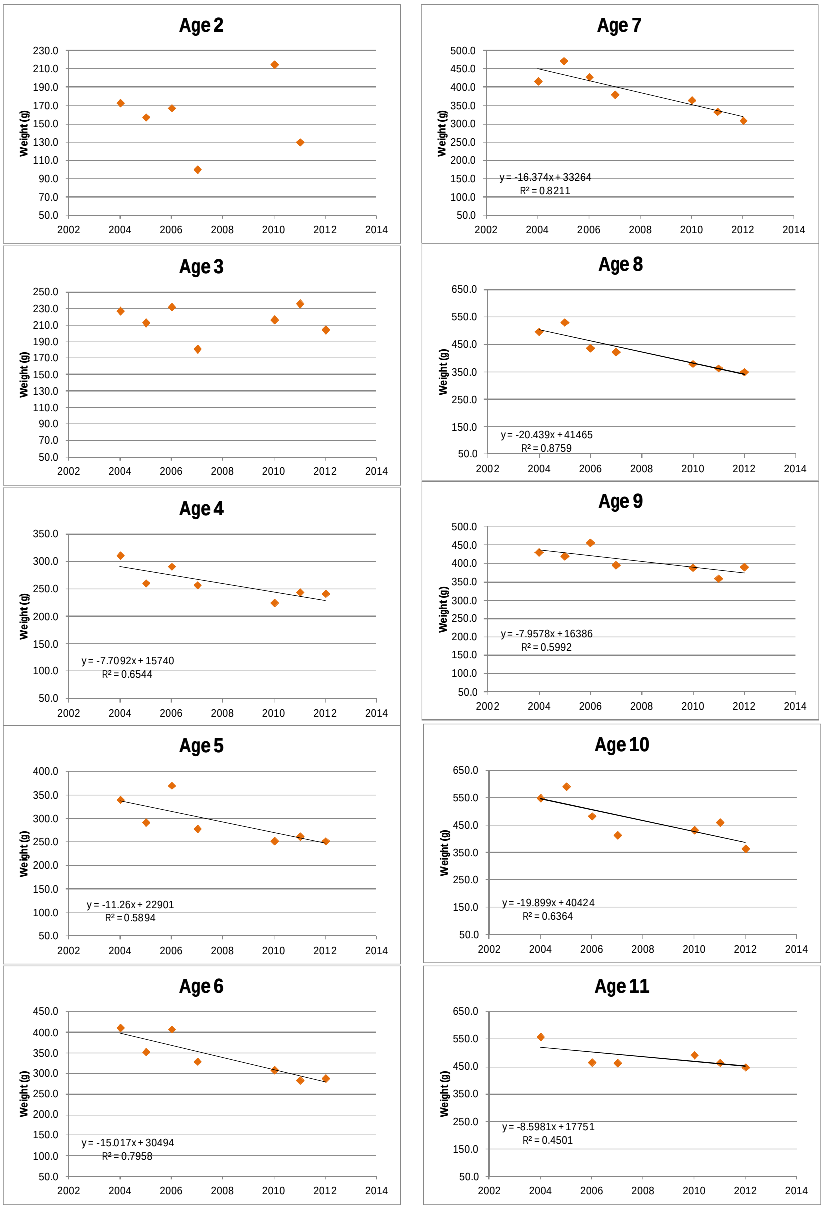

Figure 5. Mean gutted weight (TW, g) at age by year from the commercial fleet sampling for the period 1990-2012.

Mean lengths-at-age and mean total weight (TW)-at-age by year class from the commercial fleet sampling.

The mean length at age among year classes was significantly different ($p<0.05$). A decreasing trend in the mean length was observed for ages 3-8, 4-7 and 7-11, and the relationship of all of them were highly significant (p<0.000) (Figure 6). In Ages 1-3 (p=0.545) no decrease trend in the mean length was observed.

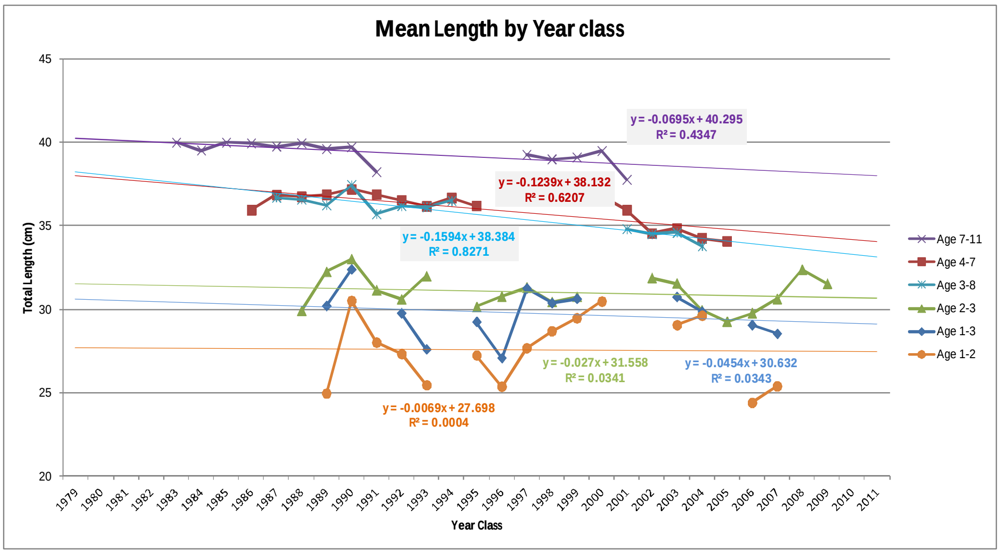

Figure 6. Mean length (cm) at age by year class and age

The mean weight at age among year classes was significantly different. A decreasing trend in the mean weight at age was observed overall for ages 3-8, 4-11 and 7-11, and the relationship of all of them were highly significant (p=0.000) (Figure 7). Again for young fish -ages 1-3 -(p=0.379) no significant decreasing trend in mean weight was observed.

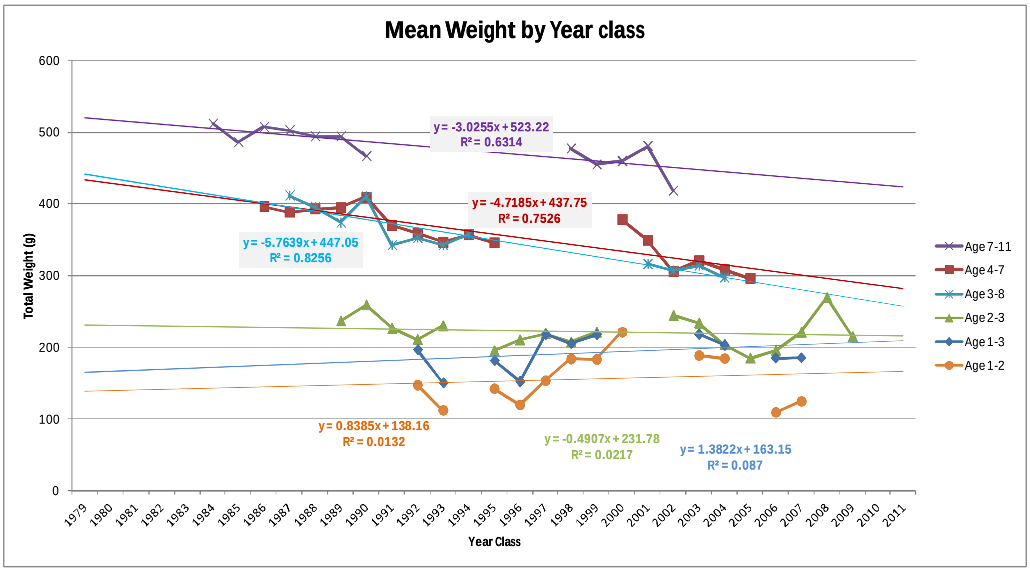

Figure 7. Mean total weight (g) at age by year class and age

The linear relationship among logarithms of weight and age were all significant (p<0.05). Instantaneous growth rates, i.e. the slopes of each linear relationship, strong year classes, well above the average (2002, 2005 and 2006) are smaller than those of weaker year classes, below average (1990, 1998 and especially 2000) (Figure 8).

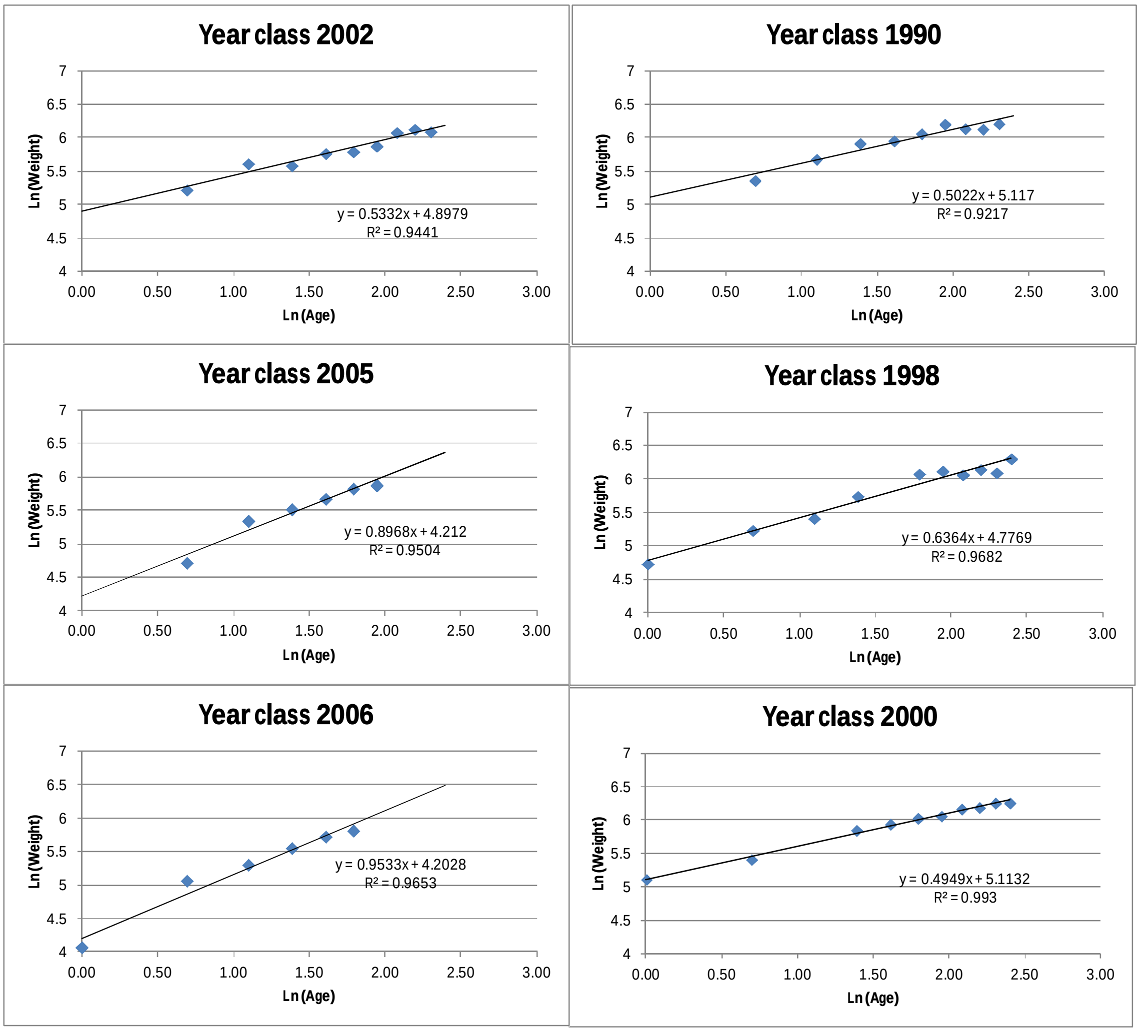

Figure 8. Instantaneous growth rate (slope of linear regressions) calculated on weight at age values (from commercial fleet) for mackerel of strong year classes, well above the average (2002, 2005 and 2006 year classes, left panel) and those weak year class, below average (1990,1998 and especially 2000, right panel)

Length-weight relationships (LWRs)

The length-weight relationship (LWRs) of mackerel (sex combined) were calculated for specimens from Cantabrian Sea (Division VIIIc) during the spawning season since 1990. The number of specimens processed, range of length (cm), parameters *a* and *b* of the LWRs, CVs, and the coefficient of correlation can be seen in Table 1. The overall results are shown in Figure 9 and Table 1. Annual LWRs lined up exponentially. Also a logarithmic transformation was used to express these relationships, using a linear regression (Figure 8). All relationship were significant ($p<0.05$). We didn't find any significant differences in the slopes (coefficient b) of annual relationships (p = 0.073 for the commercial fleet and p = 0.434 for the survey).

Table 1. Annual relationship between W (Total weight, g) and TL (Total length, cm) of mackerel, from commercial fleet and acoustic survey (PELACUS) sampling, 1990-2012.

YEAR	SEX COMBINED		Commercial Fleet SEMESTER 1				SEX COMBINED		PELACUS survey (march-april)			
	Parameter		r^2	CV	Lmin-Lmax	n	Parameter		r^2	CV	Lmin-Lmax	n
1990	a	0.006105	0.90	0.443	21-47 cm	108	a					
	b	3.055416		0.037			b					
1991	a	0.000393	0.95	0.586	29-44 cm	77	a					
	b	3.80345		0.03			b					
1992	a	0.001477	0.90	0.297	26-44 cm	247	a	0.007266	0.90	0.334	29-45 cm	200
	b	3.429406		0.023			b	2.997862		0.027		
1993	a	0.003762	0.97	0.312	23-48.2 cm	245	a	0.006899	0.99	0.085	19-46 cm	695
	b	3.199587		0.026			b	3.007215		0.008		
1994	a	0.002878	0.98	0.12	23-46 cm	488	a	0.005474	0.95	0.239	23-45 cm	274
	b	3.261027		0.01			b	3.079413		0.02		
1995	a	0.000823	0.96	0.311	24-46 cm	276	a					
	b	3.619226		0.022			b					
1996	a	0.002667	0.98	0.204	24-47 cm	257	a	0.00157	0.96	0.3	22-44 cm	208
	b	3.271102		0.016			b	3.416575		0.024		
1997	a	0.002787	0.98	0.202	20-46 cm	352	a	0.003146	0.99	0.112	21-46 cm	652
	b	3.271522		0.018			b	3.228181		0.01		
1998	a	0.012636	0.91	0.203	24-44 cm	416	a	0.005454	0.98	0.079	22-45 cm	1099
	b	2.824745		0.02			b	3.069839		0.007		
1999	a	0.006306	0.92	0.253	26-44 cm	261	a	0.001937	0.99	0.111	21-45 cm	1125
	b	3.027028		0.022			b	3.342015		0.009		
2000	a	0.003297	0.94	0.137	25-46 cm	408	a	0.003787	0.99	0.093	21.6-44 cm	915
	b	3.214982		0.012			b	3.16564		0.008		
2001	a	0.001589	0.94	0.258	27-45.2 cm	226	a	0.005704	0.97	0.099	23.6-48.4 cm	1208
	b	3.424082		0.021			b	3.06528		0.009		
2002	a	0.008978	0.92	0.225	28.2-45 cm	316	a	0.002385	0.97	0.158	12.6-45.1 cm	939
	b	2.936124		0.021			b	3.299094		0.014		
2003	a						a	0.004273	0.99	0.062	20.5-43.4 cm	946
	b						b	3.135357		0.006		
2004	a	0.001435	0.95	0.156	24.7-45 cm	972	a	0.004625	0.98	0.057	21.1-46.6 cm	1302
	b	3.457899		0.012			b	3.11785		0.005		
2005	a	0.006295	0.90	0.16	26.9-45.2 cm	864	a	0.004161	0.98	0.136	21-44.5 cm	352
	b	3.039148		0.014			b	3.151887		0.012		
2006	a	0.002889	0.90	0.158	27.6-43.8 cm	898	a	0.005046	0.98	0.092	19.4-45.1 cm	1177
	b	3.251847		0.013			b	3.084882		0.008		
2007	a	0.003958	0.94	0.112	19.5-44 cm	1485	a	0.005727	0.98	0.087	20-46.9 cm	1122
	b	3.172153		0.01			b	3.044376		0.008		
2008	a	0.007181	0.94	0.119	21-44.2 cm	1039	a	0.005887	0.99	0.078	22.2-44 cm	1035
	b	3.005294		0.011			b	3.037416		0.007		
2009	a	0.004291	0.91	0.133	25.3-44.9 cm	1006	a	0.004489	0.97	0.072	21.5-44.4 cm	1304
	b	3.147422		0.012			b	3.131787		0.006		
2010	a	0.004219	0.93	0.097	22.1-44.5 cm	1481	a	0.005707	0.98	0.046	20.3-43.9 cm	3438
	b	3.161481		0.009			b	3.05148		0.004		
2011	a	0.00528	0.88	0.134	28.9-44.1 cm	711	a	0.005141	0.97	0.143	21.5-44.8 cm	809
	b	3.095393		0.012			b	3.090588		0.013		
2012	a	0.004703	0.88	0.183	29.5-42.5 cm	659	a	0.005478	0.99	0.101	20.3-46.7 cm	931
	b	3.112219		0.016			b	3.073893		0.009		

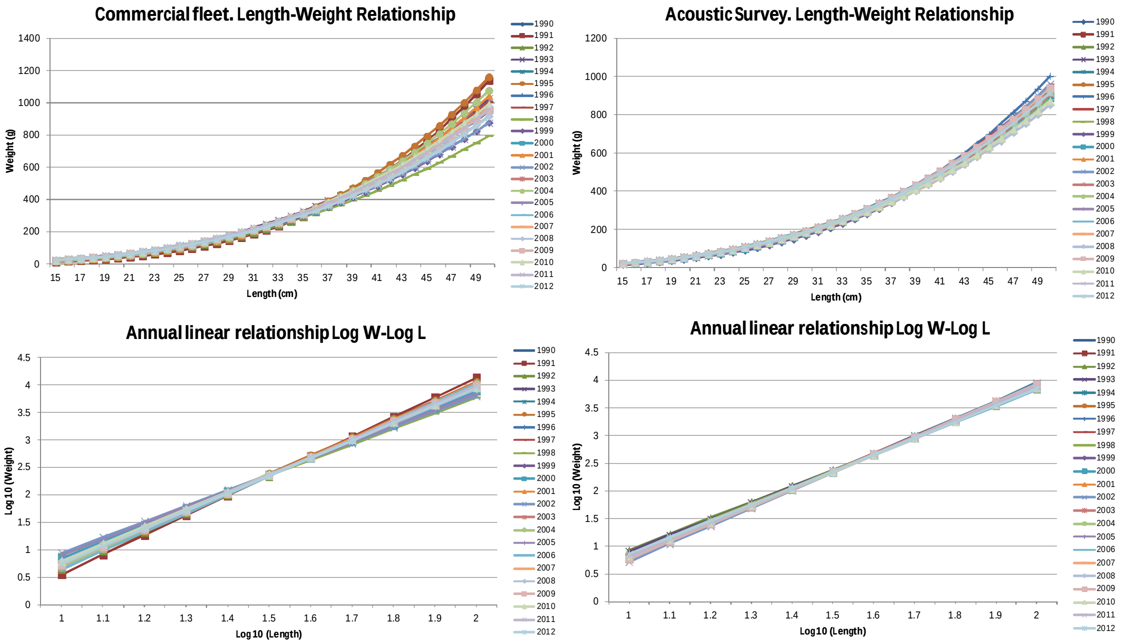

Figure 9. Annual weight-length relationships (upper panel) and annual linear relationships (bottom panel) between logarithms of weight and length for mackerel sampled from the commercial fleet and acoustic survey, 1990-2012.

The b values of the mackerel (sex combined) ranged from 2.825 (CV=0.02) in 1998 to 3.803 (CV=0.03) in 1991 from commercial fleet and from 2.998 (CV=0.03) in 1992 to 3.342 (CV=0.01) in 1999 (Table 1 and Figure 10). For commercial fleet, the lower values (below 3), were recorded in 1998 and 2002. In 1990, 1999, 2005 and 2008 b values were equal to 3, and the remaining years b values were above 3. The allometric value of b, above 3, was lower in the 2000s, especially after 2009. This means that the larger mackerel have increased less in weight respect to size, or large individuals are thinner compared to small in the 2000s compared to 90s. For PELACUS survey, most of years have b values very close to 3, except in 1997 and 1999- 2005 which are b values above 3. No year with b values below 3 has been found. In the second part of the 2000s, b values are similar for the fleet and for the survey; however, in previous years these values greatly fluctuated. A decreasing trend for b values from commercial fleet is observed in the period of study (Figure 10).

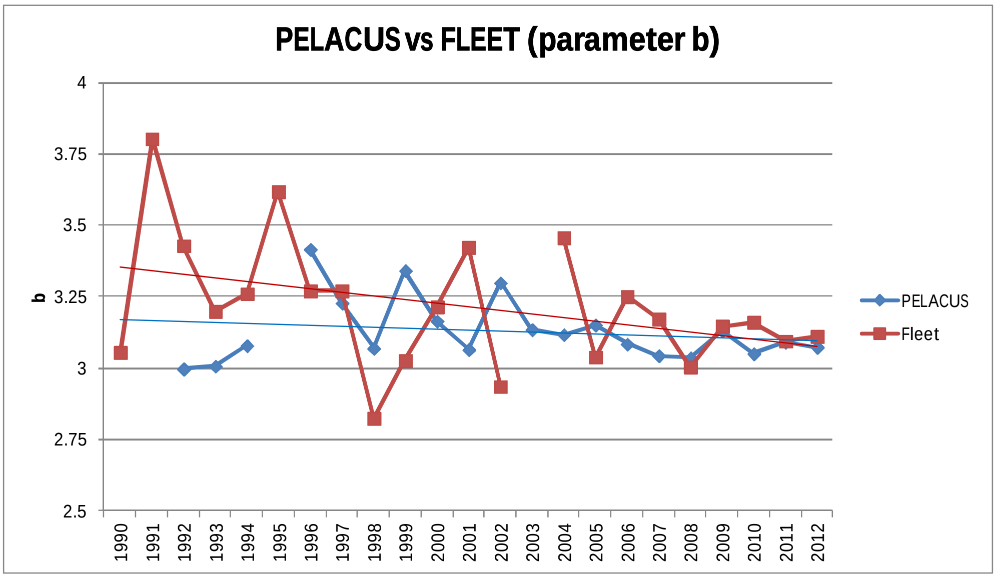

Figure 10. Annual variation of the values of regression coefficient (b) during 1990-2012.

Relative condition and relative weight

A robust regression analysis of log a over b did not find any outlier (p=0.000) and its linear regression explains 99% of the variance. Therefore, all year data were retained for this for analysis (Figure 11).

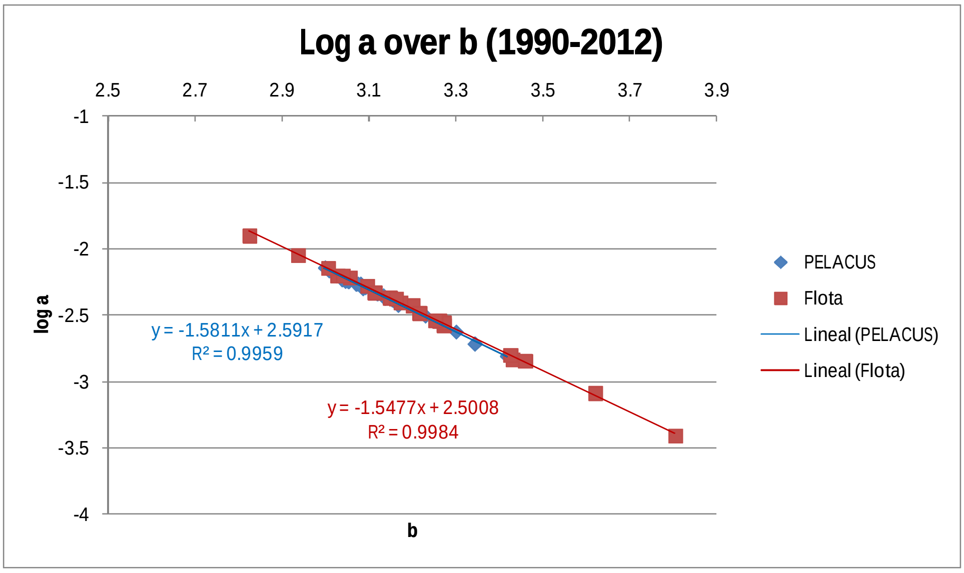

Figure 11. Plot of log a over b for 22 weight-length relationships of mackerel from commercial fleet and for 20 weight-length relationships of mackerel from acoustic survey (PELACUS).

Probably the variation of condition factor, would lead variation in parameters a and b, which in turn could explain, condition factor variations due to seasonal changes, geographic, climatic or other.

Figure 12 shows Log-log plot of condition vs length from commercial fleet, calculated from weight-length relationships of mackerel taken for each year (1990-2012). In most of the years reported here, except in 1990, 1998, 1999, 2002, 2005, 2008 and 2012, large specimens have higher condition than small specimens, as indicated by exponent b>3. In 1998 and 2002 b was smaller than 3, meaning that large specimens had lower condition than the smaller. In 1990, 1999, 2005, 2008 y 2012 b equals 3. The dotted line is base on geometric mean a and mean b of all LWRs of this species during period of study. It shows that small specimens have a lower condition than average for this species in 1991, 1992, 1995, 1996, 2001 and 2004. Adults had a lower condition than average in 1998, 1999 and 2002. Since 2005 juveniles have a condition above the average and adults have a condition at the same level as the average

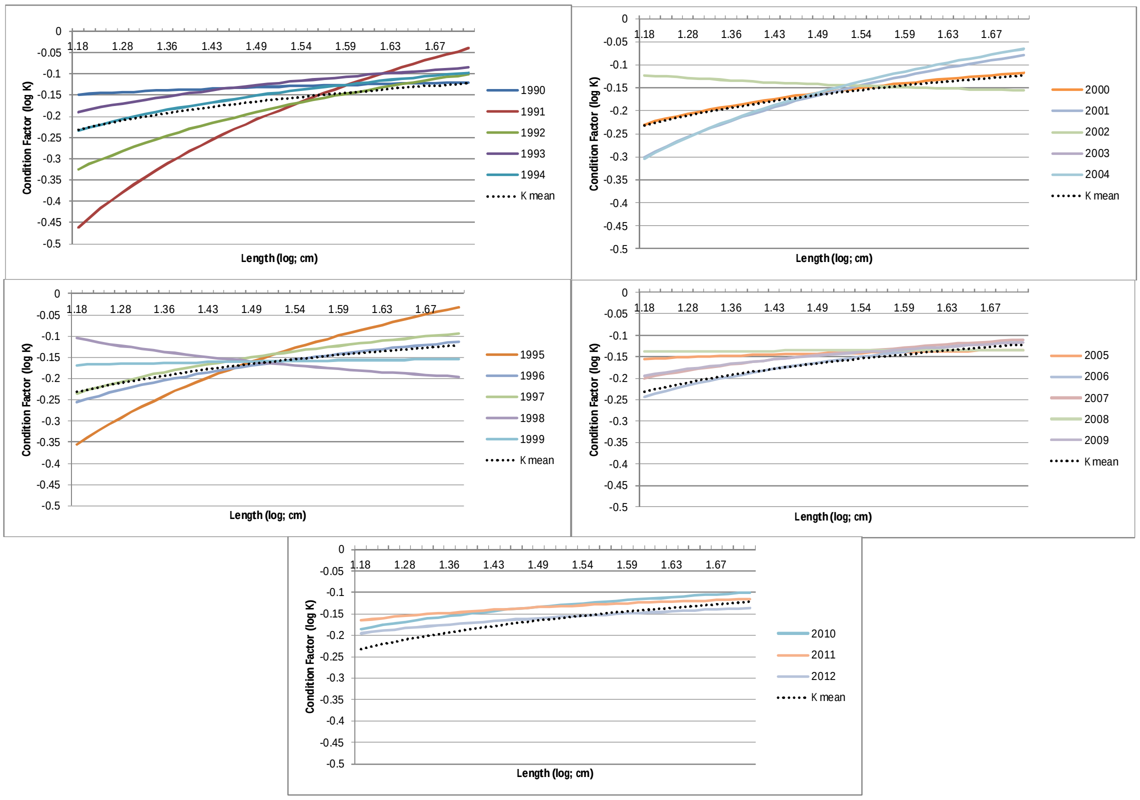

Figure 12. Log-log plot of condition vs length calculated from weight-length relationships of mackerel taken in 1990-2012 in Cantabrian Sea during the Spawning season, from commercial fleet. Dotted line shows condition factors associated with geometric mean *a* and *b* across all available WLRs for this species.

The relative weight (Wr) by years in the spawning season (Figure 13), for different sizes, shows that in the 90s the Wr fluctuates widely for all sizes, especially for the smaller sizes, this may reflect recruitment differences. In the last decade there is a slight increase of Wr for sizes 20, 25 and 30 cm (this is contrary to the density dependence, as it is the decade in which there have been major recruiting well above average as 2002 , 2005 and 2006), especially for commercial fleet data, however, for the larger sizes remains more or less constant.

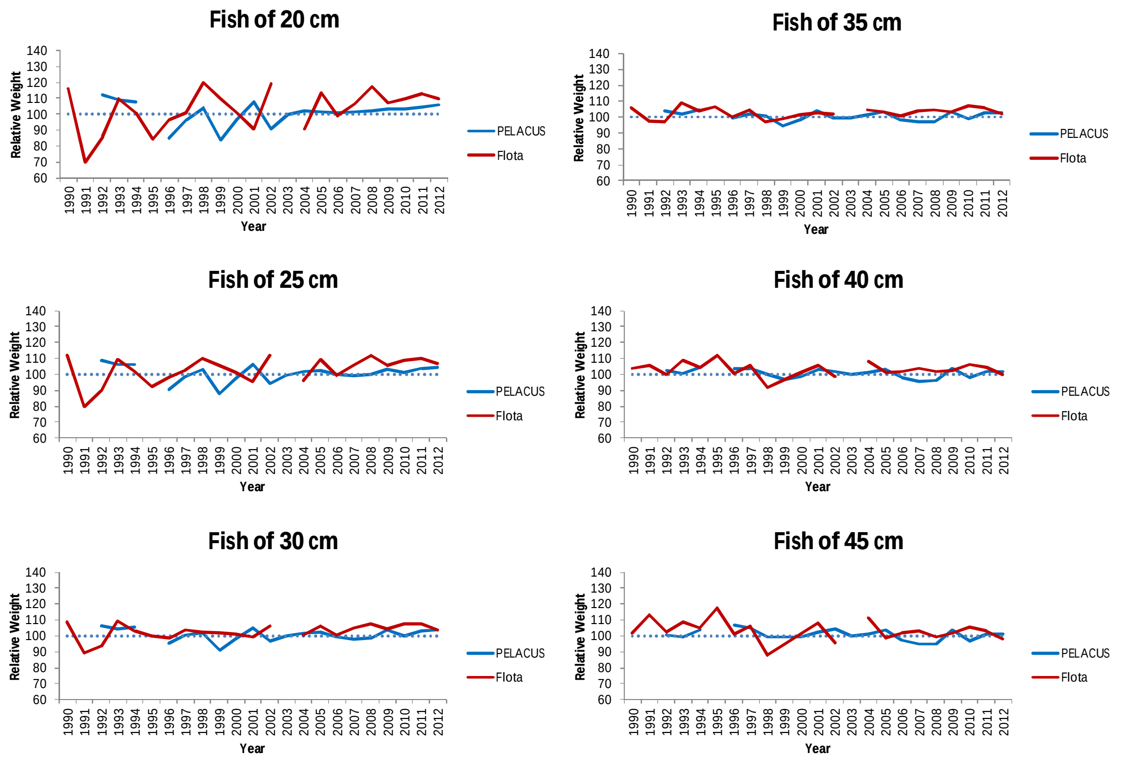

Figure 13. Relative mean weight (W_{rm}) of a various sizes fish (20 cm, 25 cm, 30 cm, 35 cm, 40 cm and 45 cm) throughout the study period (1990-2012) from commercial fleet and acoustic survey (PELACUS).

For a complete analysis of the weight (W) we have included the calculation of mean relative weight (Wrm) by size range (Figure 14). The relative weight is fairly constant across most length classes for the years 1994, 1996, 2000 and 2006. In contrast, the Wrm generally increases with the size at the years 1991, 1992, 1995, 2001 and 2004. Flat values are observed between 31 to 35 cm length classes in almost every year. And there is a decline Wrm through size classes in 1998, 1999, 2002, 2005 and 2008, mainly stronger in 1998 and 2002

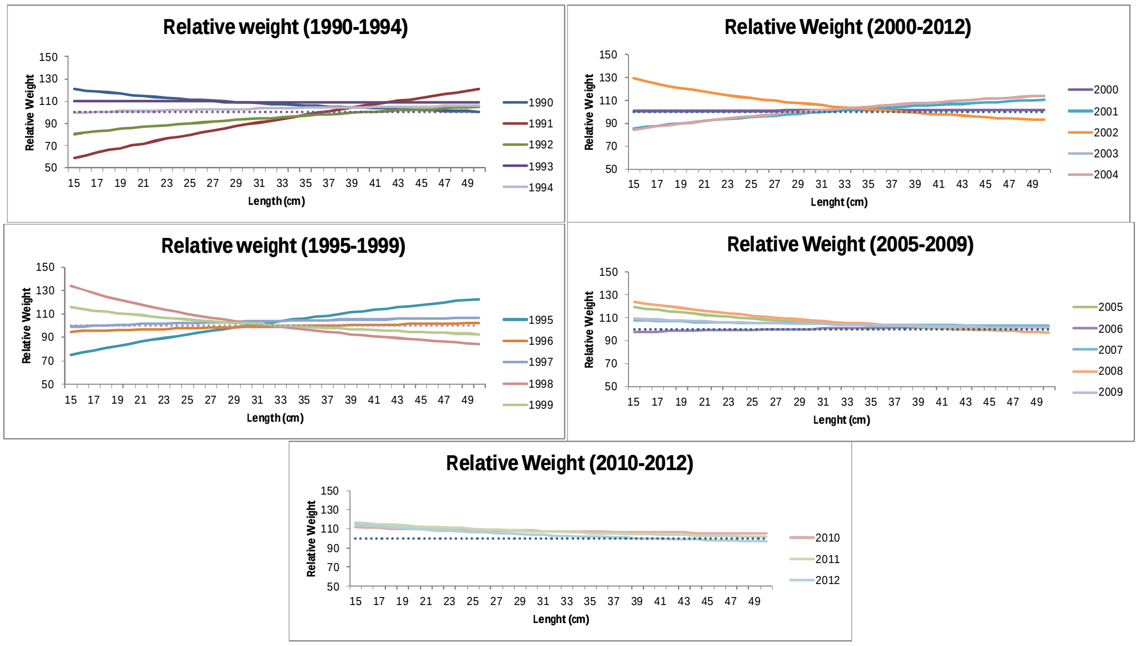

Figure 14. Relationship of mean relative weight (W_{rm}) to total length, in 1-cm length classes, for 1990-2012, from commercial fleet.

Maturity and Weight of Gonads

The mean weight increased from stage 1 to stage 4 (Figure 15). It subsequently decreased because of the onset of spawning. In the last decade, a decreasing trend in the mean weights of gonads was observed in the active stages (3, 4 and 5), mainly in Stage 3 (pre-spawning) and the relationship was significant ($p < 0.05$) (Figure 16).

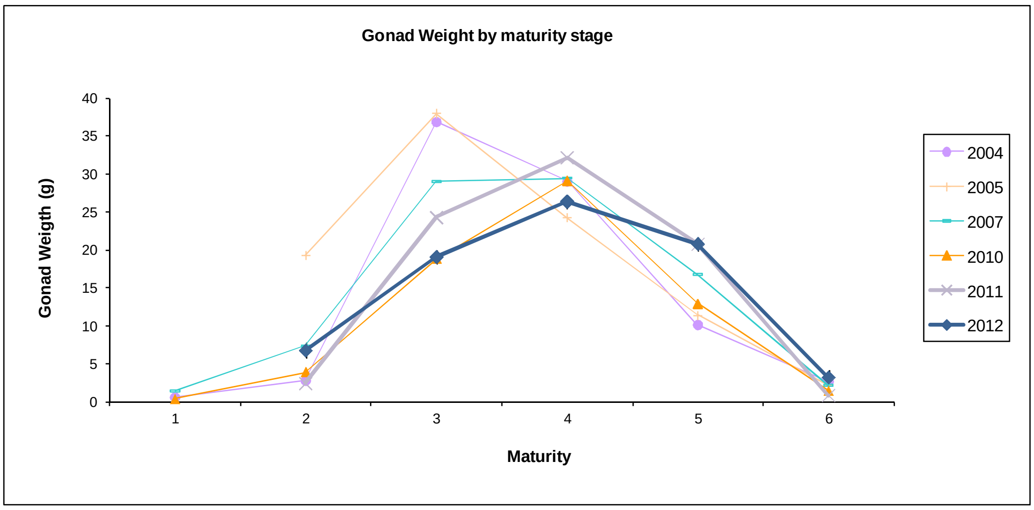

Figure 15. Mean gonad weight (g) by maturity stage for years 2004-2005, 2007 and 2010-2012.

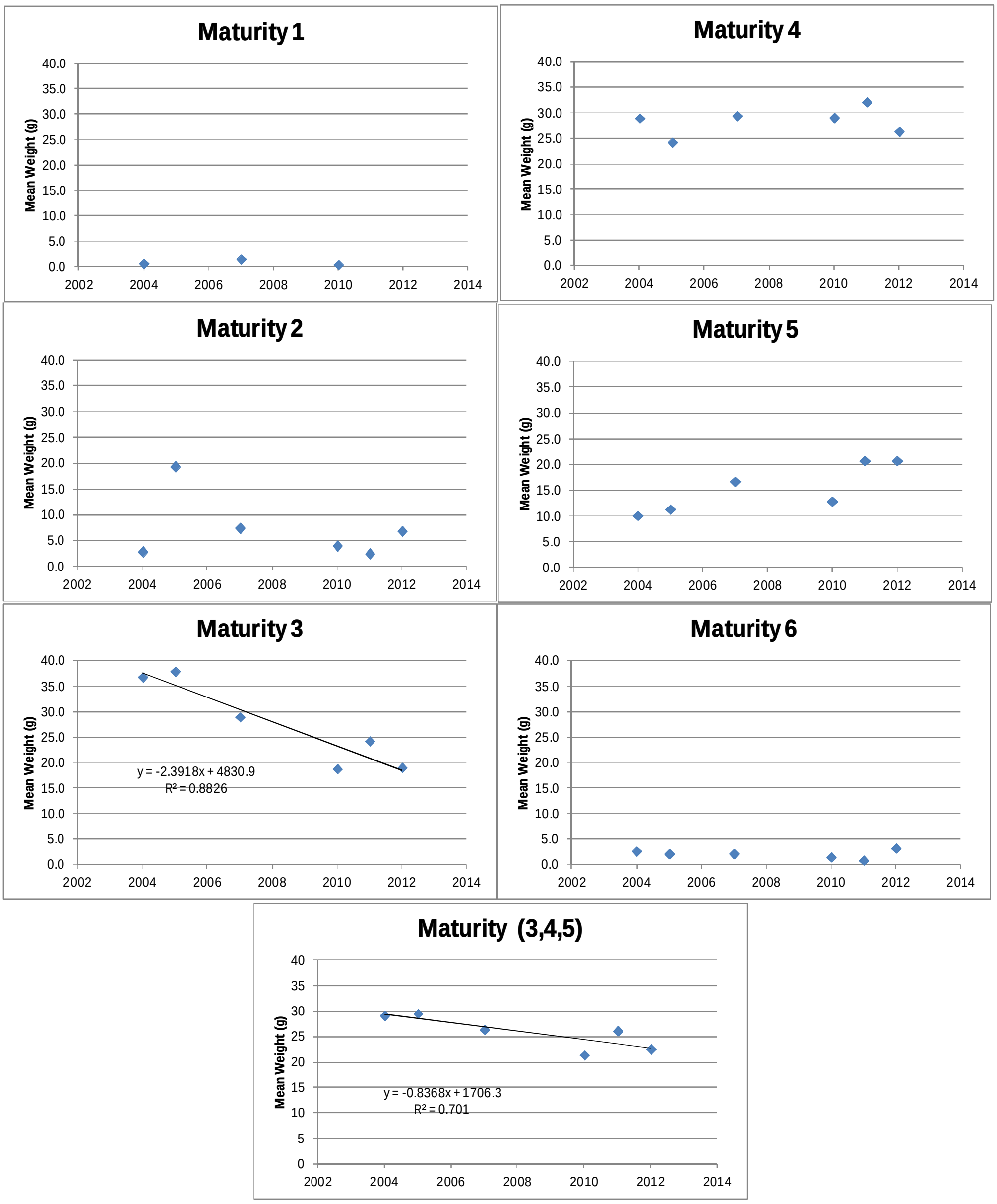

Figure 16. Mean gonad weight (g) by maturity stage for years 2004-2005, 2007 and 2010-2012.

For all study period (1990-2012) there is a decreasing trend of mean weight (TW) of mackerel for active maturity stages (mainly 3 &4), and also to the stage of maturity 2. Contrary, an increase in weight for maturity stages 1 and 6. The relationship was significant for Stages 1, 3 and 4 ($p<0.05$) (Figure 17). The size of immature Stage 1 fish in 2001 and 2010 was larger than 250 g.

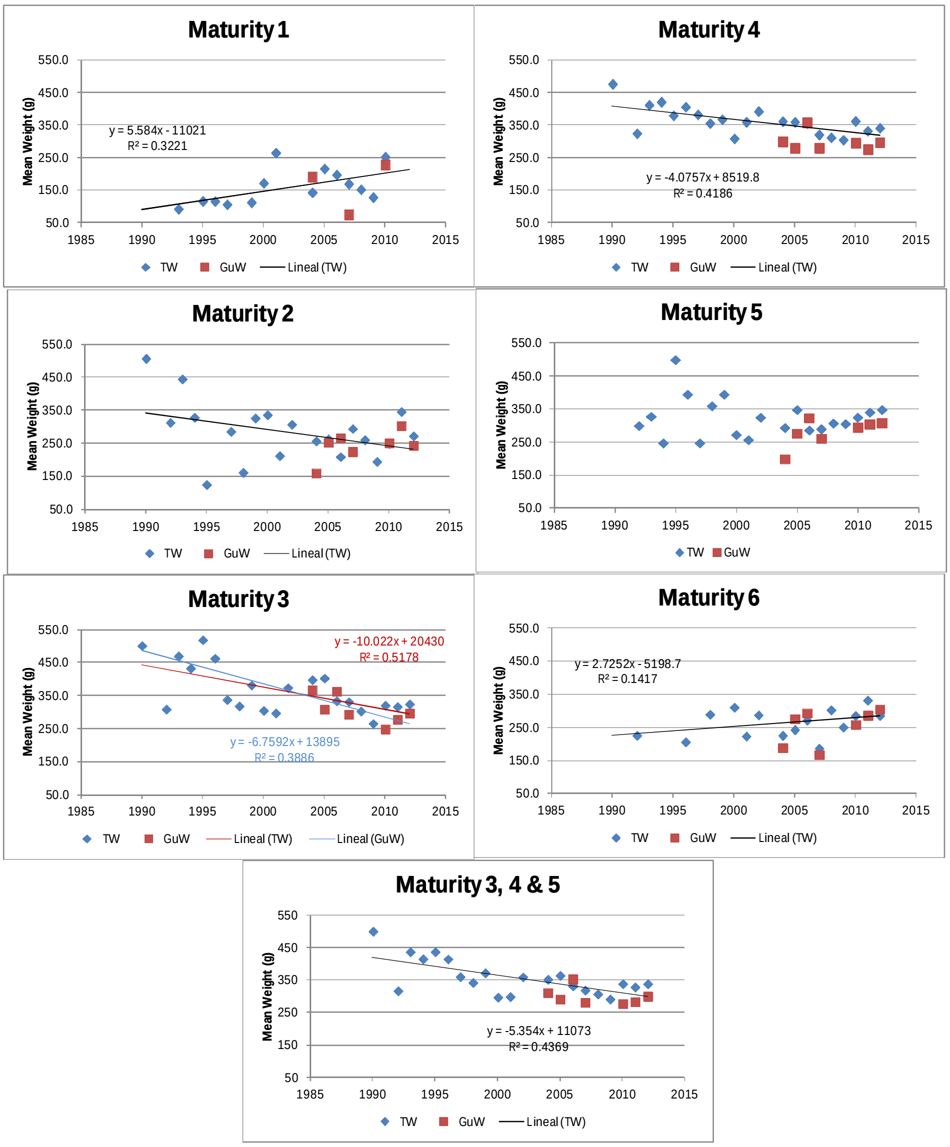

Figure 17. Mean annual total weights (TW) and gutted weights (GuW) by gonad maturity stage in mackerel sampled, 1990-2012.

Discussion

Mean length and weight-at-age showed significant annual differences. Besides, annual changes in mean length and weight at age were observed. During the last decade we can conclude that there was a decrease in mean weight at age for age group 4 and older. We believe that the reduction in weight has been mainly caused by a reduction in the weight of the gonads at spawning time, mainly in the active maturity stages (stages 3-4-5 from Walsh Scale).. Besides in spite the study didn't cover the full time series (only available data for seven year), the same pattern has been observed in gutted mean weight.

The decrease in the mean weight at age may be due to a density-dependent effect and/or a decrease in available preys (i.e. lack of food). There are references of declining the mean weights at age of the species in northern Europe and that the most plausible hypothesis would be the decrease in *Calanus* (ICES, 2012).

The lowest mean weight and mean length values were found in the 2002 and 2005 year-classes. Very strong year classes were recruited to the stock in 2002 and 2005 (ICES, 2012). This resulted in an increased abundance of mackerel in recent years using the Norwegian Sea as a preferred feeding ground (Utne, 2013). Mackerel stay in the warm upper water layers with high concentration of zooplankton during the feeding period (Iversen, 2004). On the other hand, the distribution of *Calanus finmarchicus* shifted northwards due to its affinity for colder waters causing the fish to follow its most important prey (Utne, 2013). Further, in the Norwegian Sea and in the waters east of Iceland, mackerel partly utilize the same feeding area as northern blue whiting (*Micromesistius poutassou*) and Norwegian spring spawning herring (Astthorsson, 2012). Loeng et al. (2009) pointed out that as pelagic fish biomass in the Norwegian Sea increased in recent years, zooplankton biomass decreased steadily, and suggested that the fish may be overgrazing the food resource. All these studies suggest that the change of mackerel distribution further north, involves competition for food with other species, and also for the decline in their main food (C. *finmarchicus). T*his probably involves a decrease of weight and condition observed in this study in adults of the mackerel Southern component, during the spawning season. However, in this study, we haven't found significant decreasing trend in weight nor in mean length of juvenile mackerel which corroborates the existence of different feeding areas for juveniles and adults. Accordingly, mackerel juveniles would remain in the nursery grounds located close to the main spawning areas (i.e. NW Iberian Peninsula) and once they reach sexual maturity (2-3 years old), join the adults feeding migration towards the north of Europe (Uriarte et al., 2001).

Condition factor generally shows an annual pattern, increasing it before and around the spawning season, decreasing during the spawning season due to sexual activity and then increasing again during the feeding season, after the spawning period earning enough energy (fat) to overwintering. This pattern could be change and fish decreases their condition when temperatures are low and / or when the available food is scarce. In this adult mackerel had a condition below average between late 90's and early 2000 and around the average in late 2000's onwards. The condition factor for juveniles during this second period was above average.

For further weight (W) population analysis, we have included the calculation of mean relative weight (Wrm) by size range (Figure 13). Although we can only speculate on the significance of these patterns, they suggest certain possibilities. Flat values among 31 to 35 cm practically every year, may be related to the high density of fish in these size classes in the study area (Punzón et al., 2004; Punzón and Villamor, 2009; Villamor et al., 1997). The strong decline of Wrm across size classes, mainly in 1998, 1999, 2002, possibly indicates competition with other species, or unfavorable environmental conditions for the larger fish. Further research is required between Wrm and other characteristics of the population and its environment, to assess the state of population status.

Surprisingly, these observed changes, most of them suggesting worse environmental factors for both mackerel somatic and gonad growth, apparently have no affected the strength of the recruitment (egg quality and larvae survival ratio). As the adult distribution area, especially during the feeding season, is increasing together with the range of the migration and even the timing of these migrations is changing, both spawning grounds and nursery areas seem to remain more stables. Nevertheless it should be noted that the ability to migrate is size/condition factor dependent; therefore, a fine monitoring of the population is suggested in order to verify if some of the adults with poor condition factor could remain in the nursery areas, thus without undertake feeding migration and changing the behaviour.

On the other hand, the reduction in weight at age could have management implications since more fish are needed to achieve the TAC.

Acknowledgements

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Working document on NSHM catches in the IBTS survey

Description of the data

Horse mackerel is abundantly caught in the North Sea IBTS survey. Survey data is available as numbers of fish (individuals) caught per hour (cpue) by length classes of 10 mm. Fish between 1-14 cm correspond to 0-year old fish and half of the individuals are mature at 23 cm. Figure 1 shows the spatial distribution of horse mackerel catches in the survey for three grouped length classes roughly corresponding to (a) 0-year old juveniles, (b) 1-, 2-, and possibly 3-year old juveniles, and (c) adults respectively. 0-year old fish are found in high concentrations in the South Eastern part of the North Sea (in area IVb and IVc), along the Dutch, German and Danish coast. 1-year and older fish are found in highest concentrations in the same region, while some concentrations are found around the Orkney Islands as well. Rückert et al (2002) described these North-West and South-East concentrations of abundance as two separate stock components in the North Sea. Results from the HOMSIR project suggested that the North Western concentrations, however, are likely horse mackerel originating from the Western stock, migrating into area IVa. Appendix 1, provides annual distribution maps of horse mackerel catches in the IBTS survey.

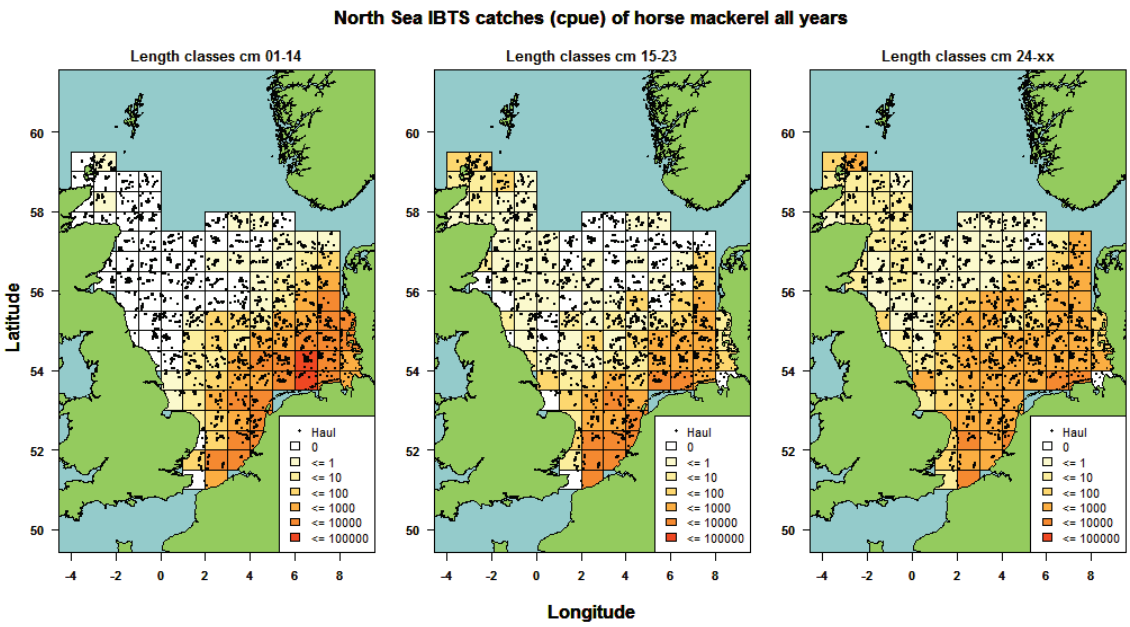


Figure 1. Distribution of horse mackerel caught in the IBTS survey.

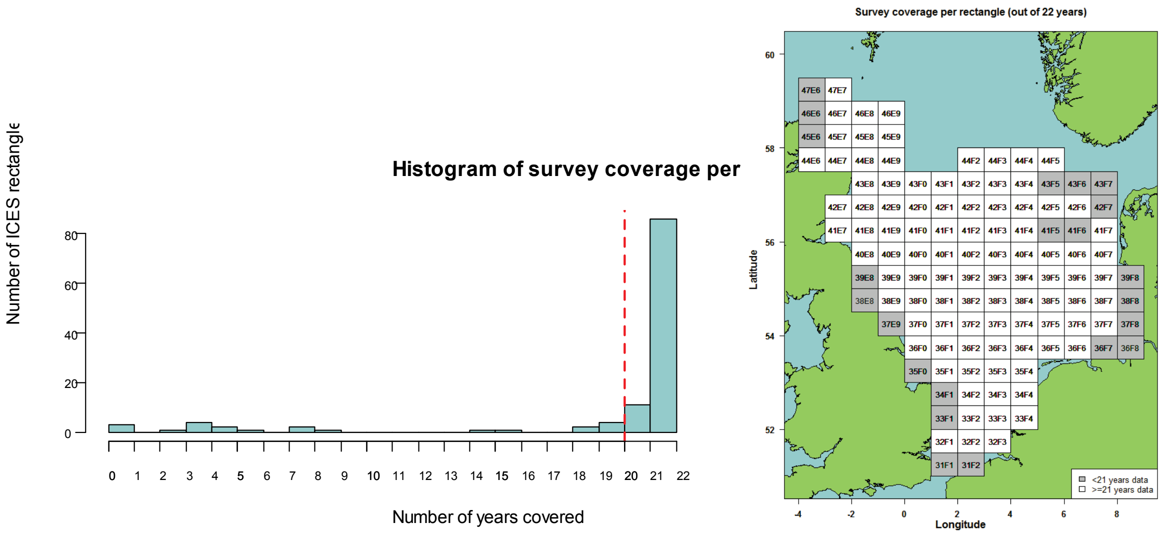


Figure 2. Coverage of individual rectangles throughout the time series of the survey. Only rectangles covered 21 or 22 out of the 22 years are included in the index area. Appendix 1, provides a spatial distribution of the coverage by rectangle.

Not all rectangles are covered in every survey year (e.g. due to weather conditions). Rectangles that were not covered more than once were therefore excluded from the index area. See figure 2. In 2007 – and in a number of subsequent years – explorations of IBTS index trends have been presented to WGWIDE. These were based on the selection of an index area on condition that the rectangles were (a) never missed in the years 1991-2006 and (b) horse mackerel catches were reasonably abundant (see figure 3; right). In 2012, WGWIDE expressed concern that using such a 'narrow' index area did not sufficiently cover the distribution area of the stock however, especially in years that the stock would be relatively more abundant and spread out more. Based on the above 61 rectangles were identified to be included in the index area as shown in figure 3 (left).

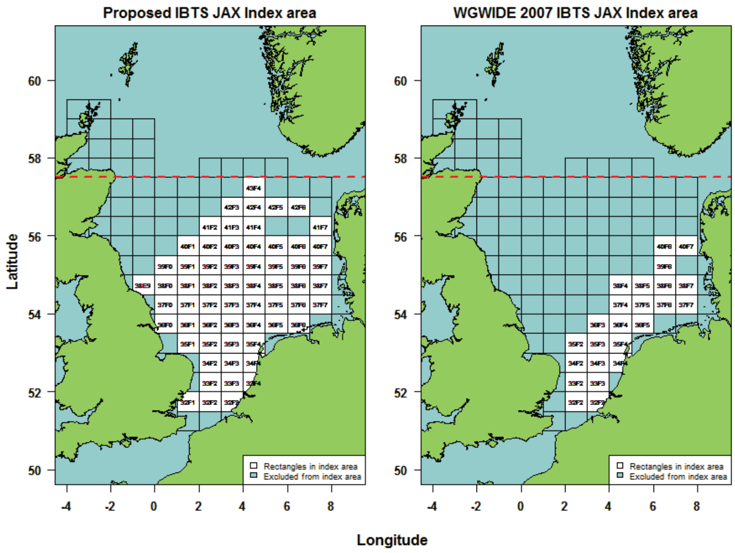


Figure 3. Index area consisting of 61 recangles (left) in comparison to previously used index area as presented to WGWIDE in 2007 (right).

As to be expected with a semi-pelagic species, the variation in numbers caught per haul is extensive. Zero catch hauls are common; of all calculated cpue values per ICES statistical rectangles (typically the mean cpue of 2 hauls) throughout the time series approximately a quarter equals zero. These are not consistently the same ICES rectangles. The mean cpue by rectangle during the time series is 1838 individuals caught per hour. Figure 4 provides an impression of the variation in the cpue values by rectangle. (see also Appendix 1, table 1).

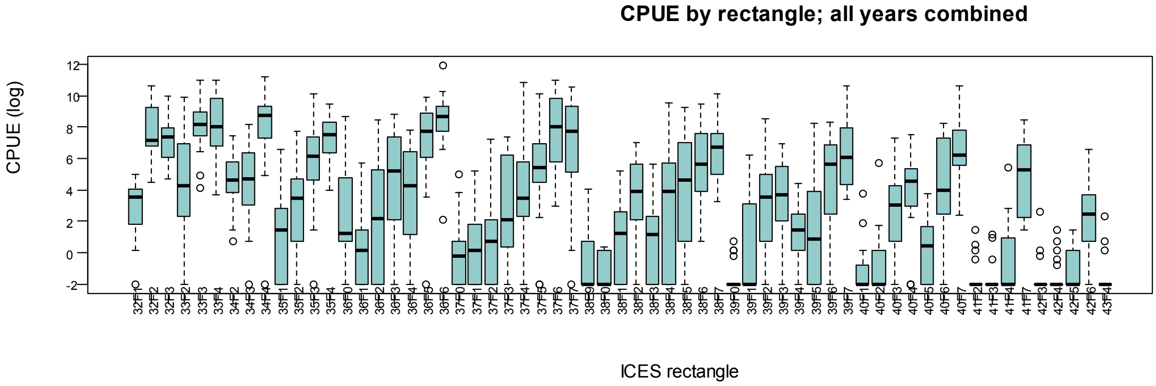


Figure 4. Cpue values by ICES rectangle for the 61 selected rectangles included in the index area.

‘Jackpot-hauls’ also occur, where an aggregation of fish is caught and the numbers are orders of magnitudes higher than the mean. In such cases one particular rectangle may have a substantial effect on the mean cpue in that year. Appendix 1 includes the relative contribution to the mean by rectangle for each year by means of annual pie charts showing the relative contribution by rectangle to the total annual cpue. Table 1 shows an overview of the number of rectangles that make up 95% of the total annual cpue.

Table 1. Number of rectangles (out of the 61 rectangles selected for the index area) that contribute 95% to the total cpue for all years.

Year	*1991*	*1992*	*1993*	*1994*	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*
Rectangles	19	15	15	18	12	21	16	19	16	11	7	13	15	13	10	11	13	12	13	7	6	4

Figure 5 shows the length distribution of the IBTS catches. (Annual length distribution histograms are provided in figures in appendix 1.) 0-year old fish can be clearly distinguished by the first peak in the distribution. Age information from the Dutch sampling programme of commercial catches showed that no 0-year old fish were greater than 14 cm. Age information from the IBTS survey in the period 2004-2009 is consistent with this as well.

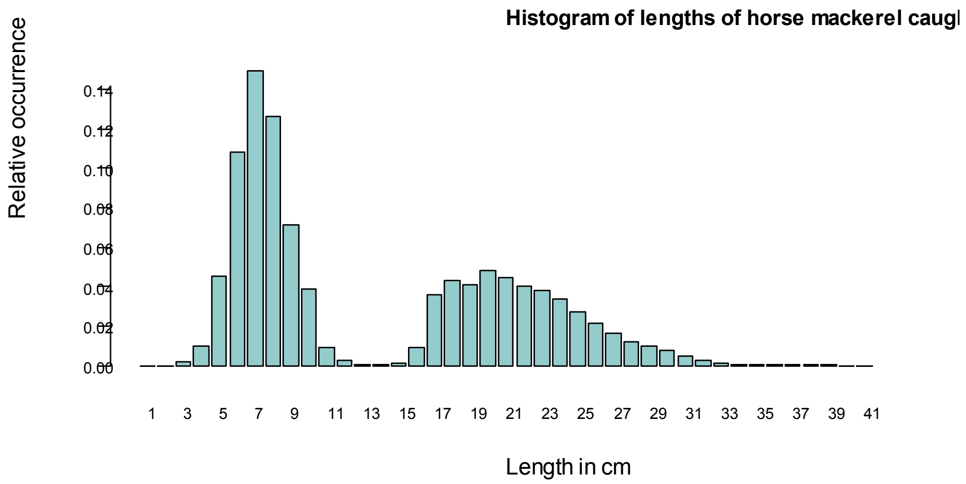
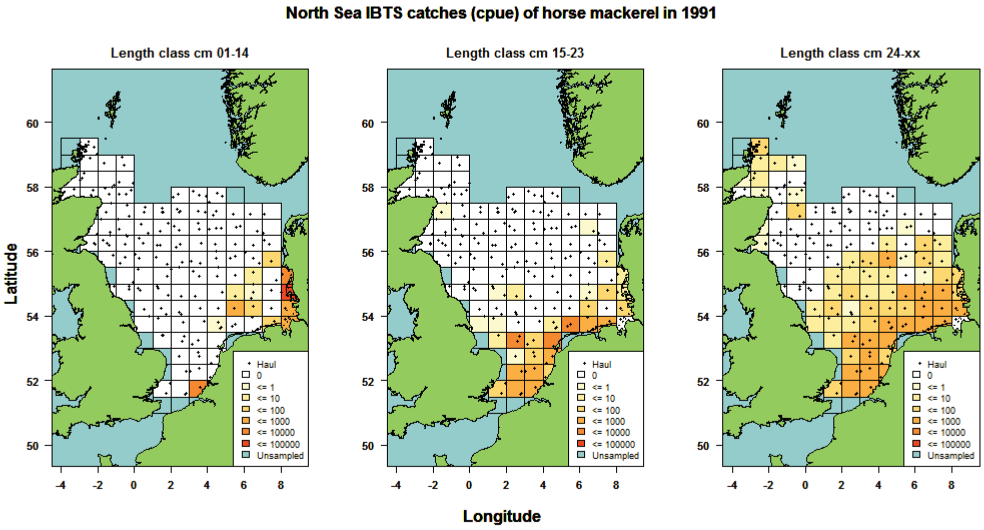
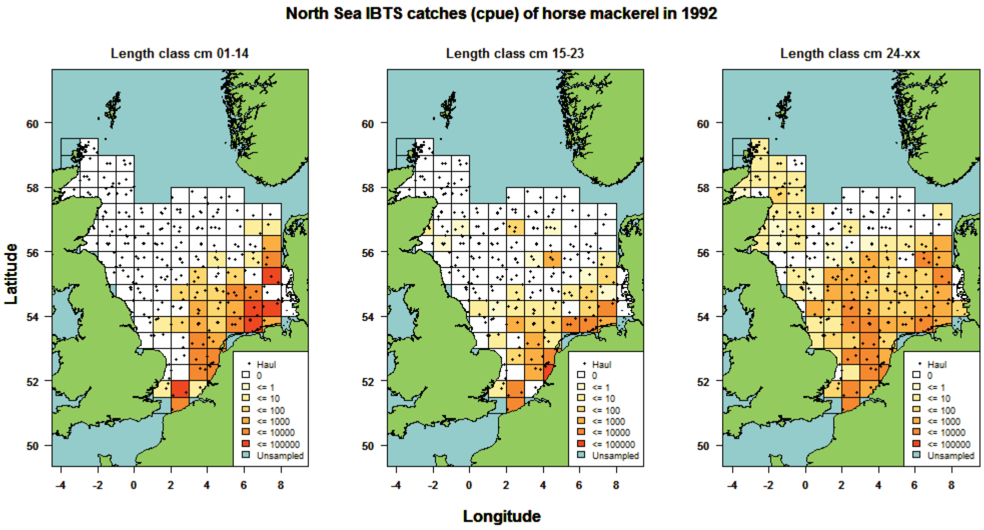


Figure 5. Length distribution of horse mackerel caught in the IBTS survey (mean over 1991-2012).

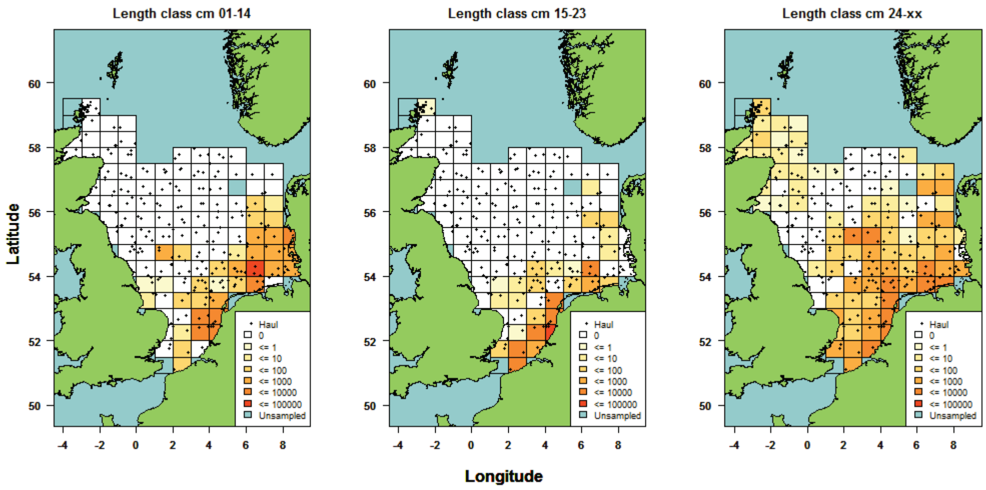
Appendix 1.



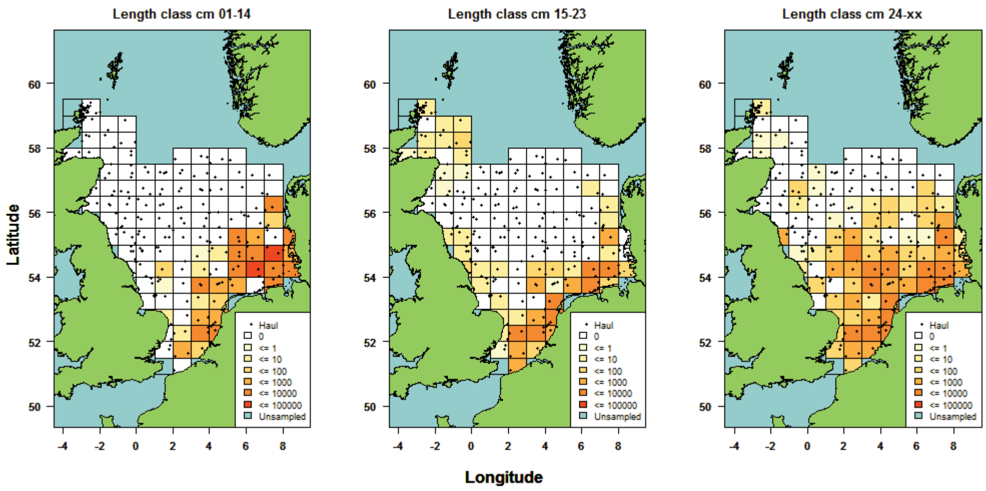


Distribution of catches in the IBTS survey by length class by year (cpue per ICES statistical rectangle). The legends show categories defined as being smaller or equal to (<=) a particular value. This should be interpreted as "being smaller or equal to this value *but larger than the value of the previous category"*. For example, "<= 1000" that *between* 100 and 1000 individuals per hour were caught.

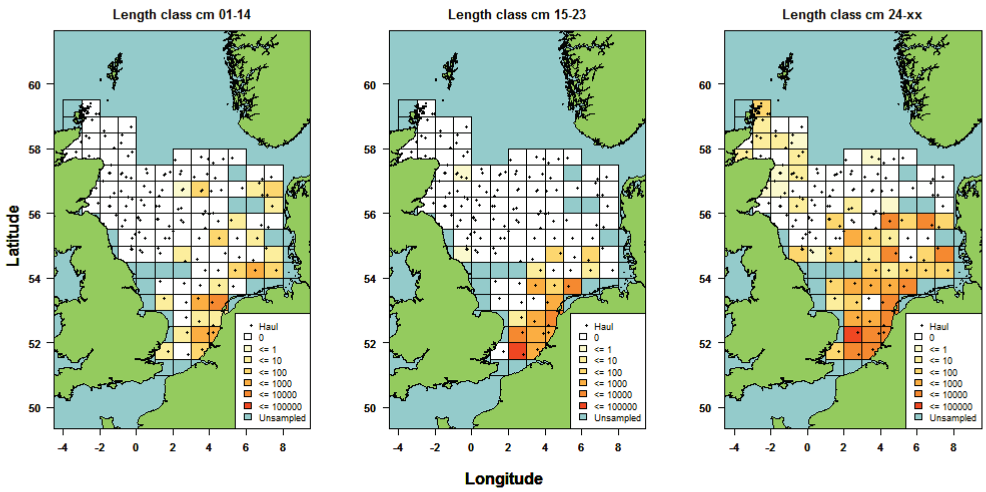
North Sea IBTS catches (cpue) of horse mackerel in 1993



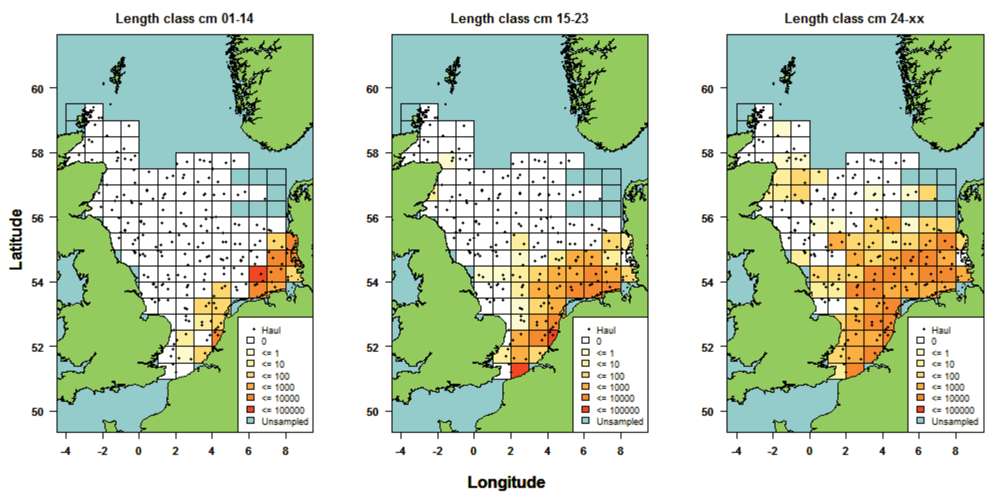
North Sea IBTS catches (cpue) of horse mackerel in 1994



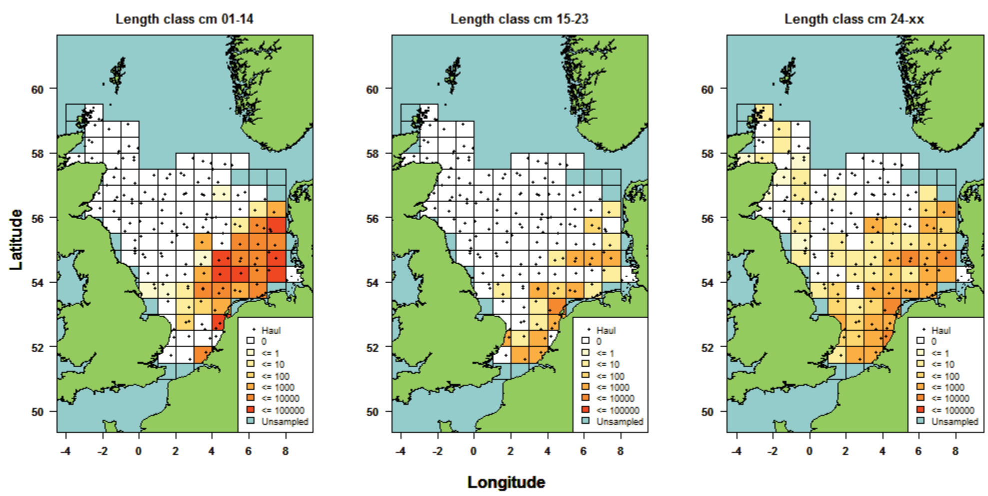
North Sea IBTS catches (cpue) of horse mackerel in 1995



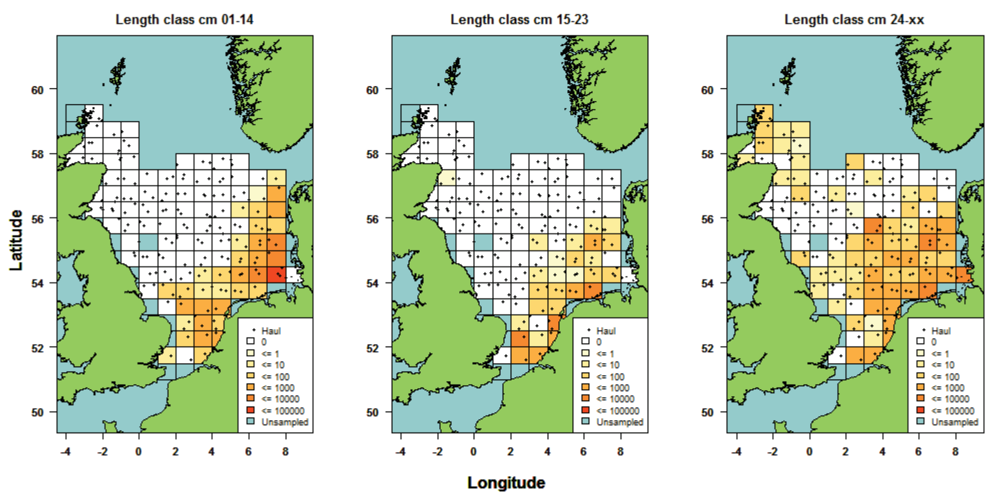
North Sea IBTS catches (cpue) of horse mackerel in 1996



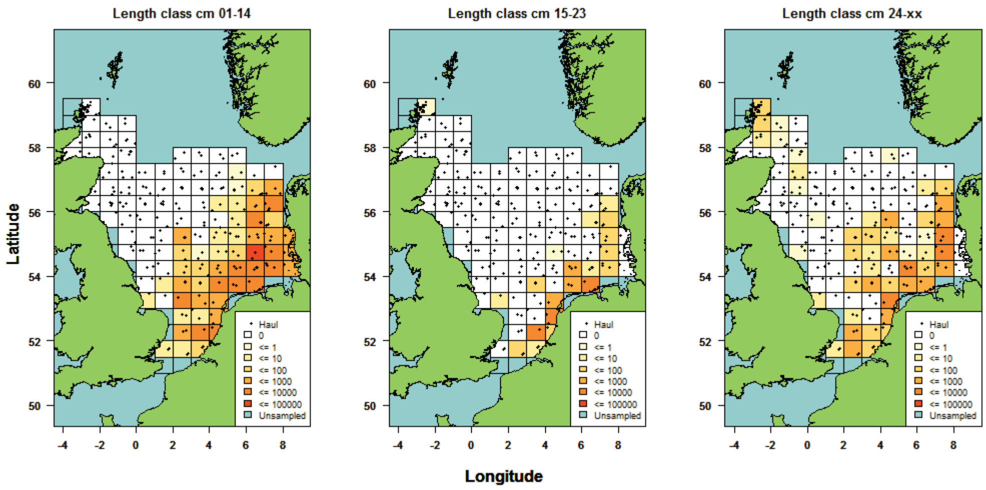
North Sea IBTS catches (cpue) of horse mackerel in 1997



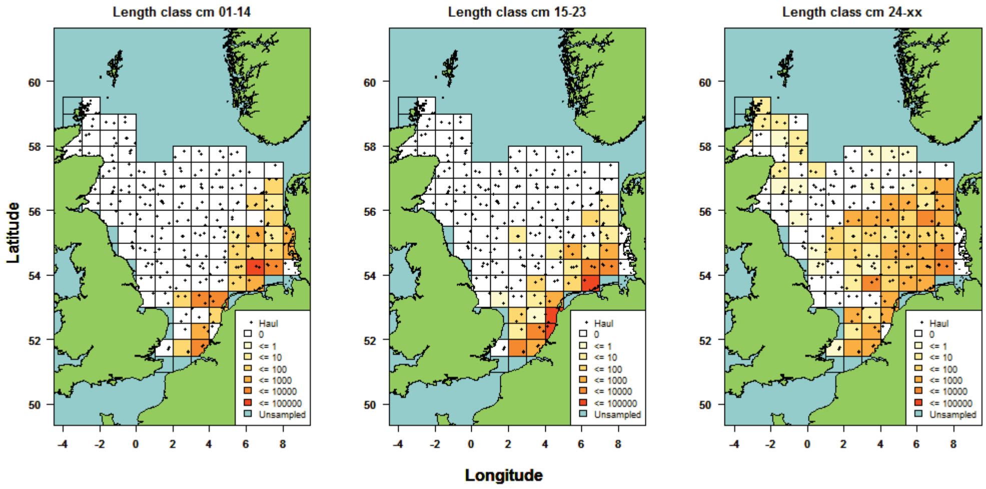
North Sea IBTS catches (cpue) of horse mackerel in 1998



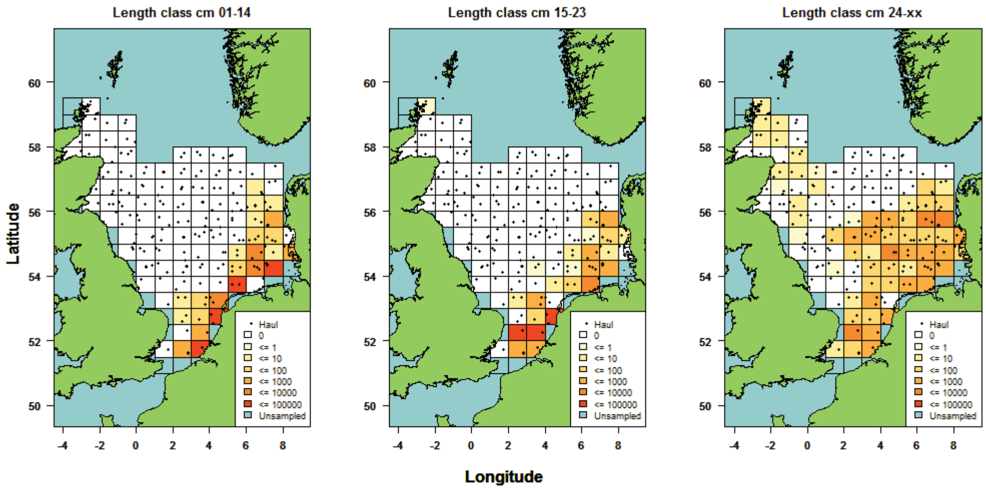
North Sea IBTS catches (cpue) of horse mackerel in 1999

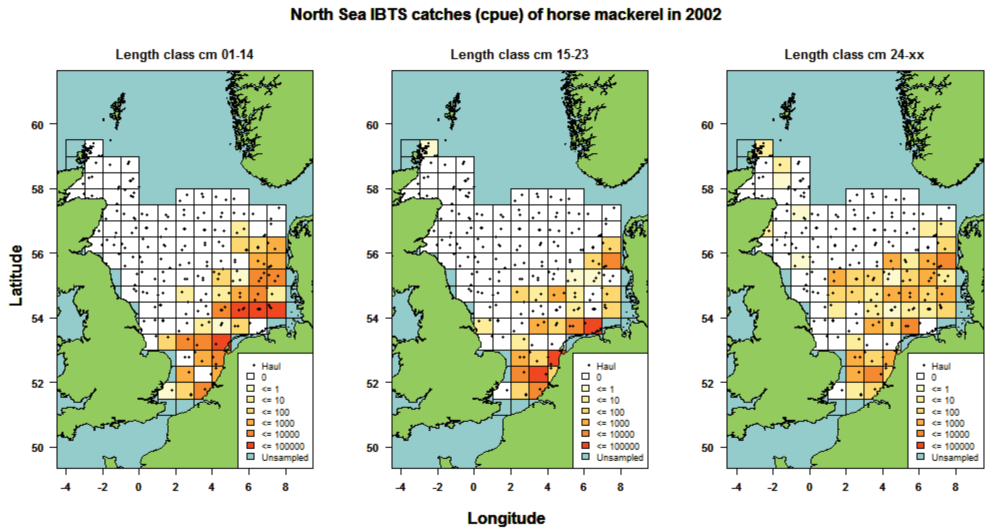


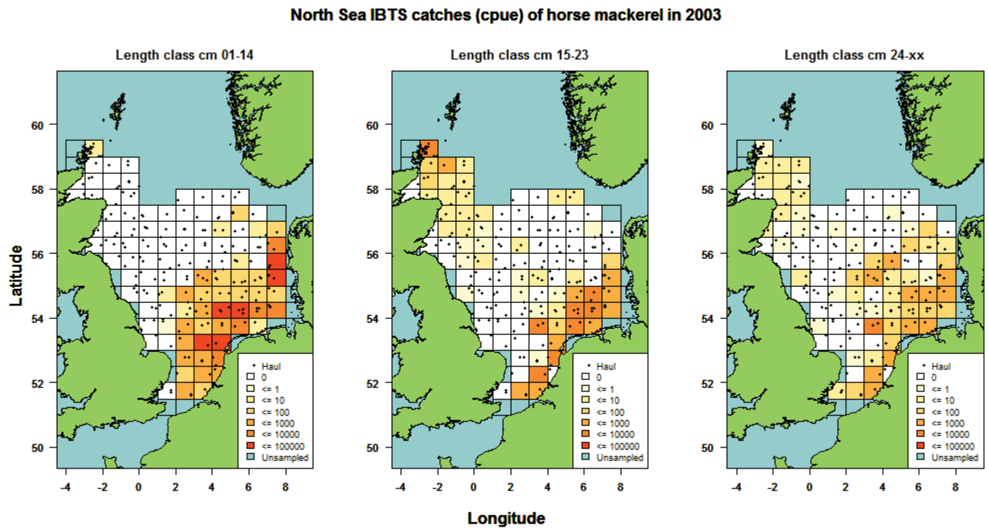
North Sea IBTS catches (cpue) of horse mackerel in 2000



North Sea IBTS catches (cpue) of horse mackerel in 2001




North Sea IBTS catches (cpue) of horse mackerel in 2002
Length class cm 01-14
Length class cm 15-23
Length class cm 24-xx
Latitude
Longitude
Haul
0
<= 1
<= 10
<= 100
<= 1000
<= 10000
<= 100000
Unsampled


North Sea IBTS catches (cpue) of horse mackerel in 2003
Length class cm 01-14
Length class cm 15-23
Length class cm 24-xx
Latitude
Longitude
Haul
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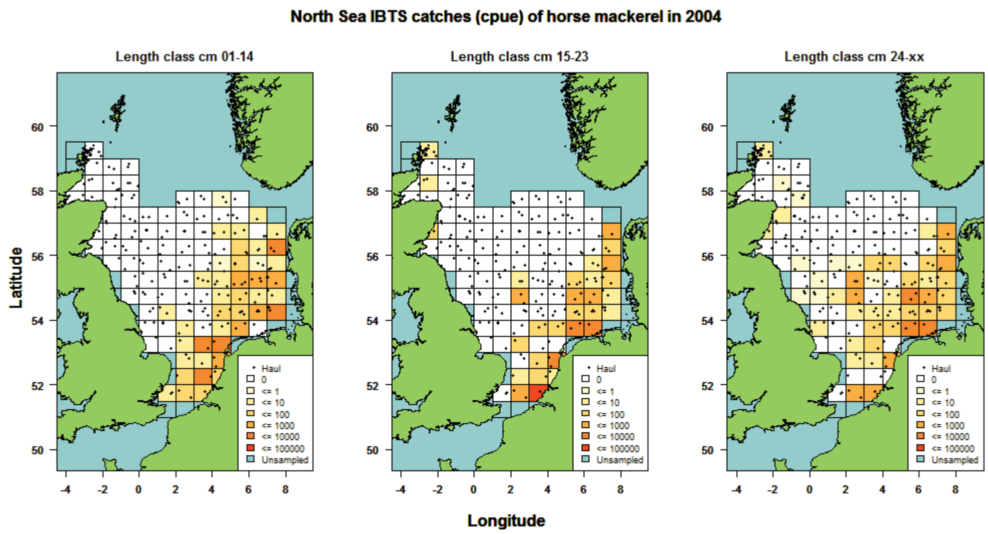
<= 1
<= 10
<= 100
<= 1000
<= 10000
<= 100000
Unsampled


North Sea IBTS catches (cpue) of horse mackerel in 2004
Length class cm 01-14
Length class cm 15-23
Length class cm 24-xx
Latitude
Longitude
Haul
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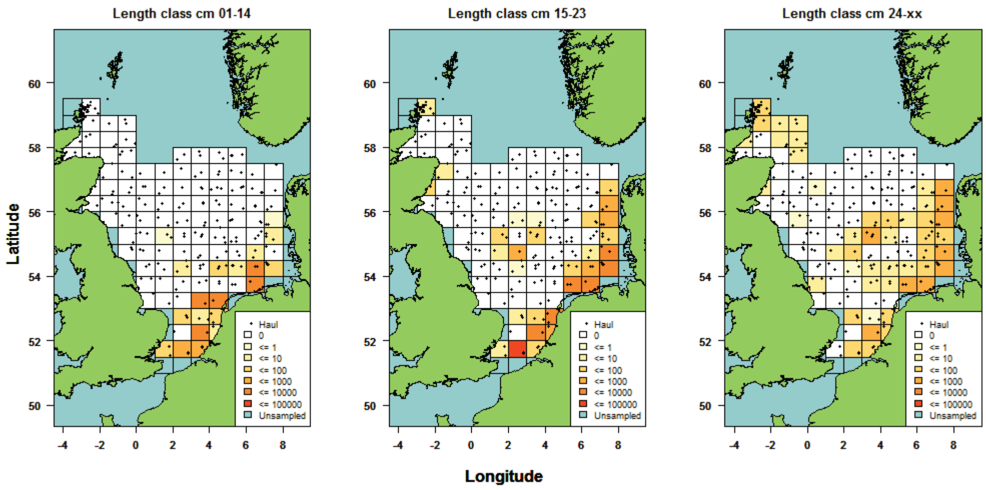
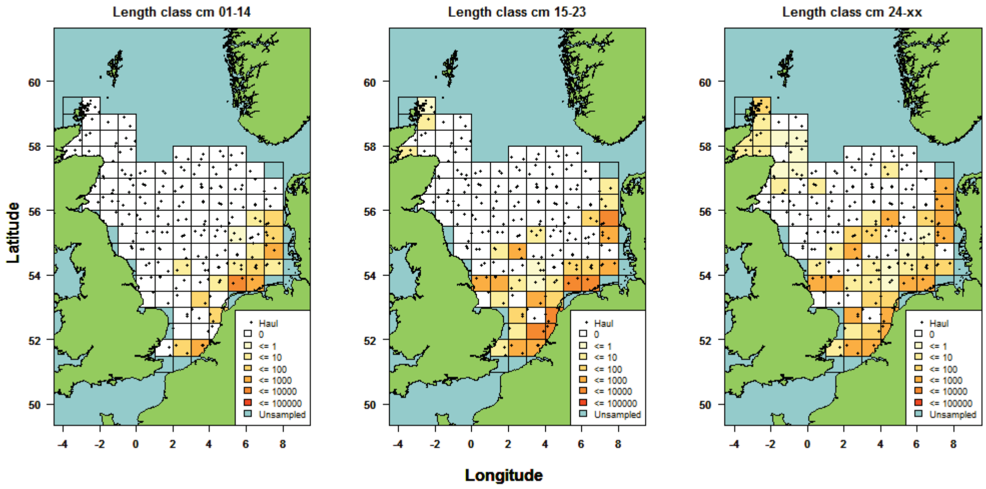
<= 1
<= 10
<= 100
<= 1000
<= 10000
<= 100000
Unsampled

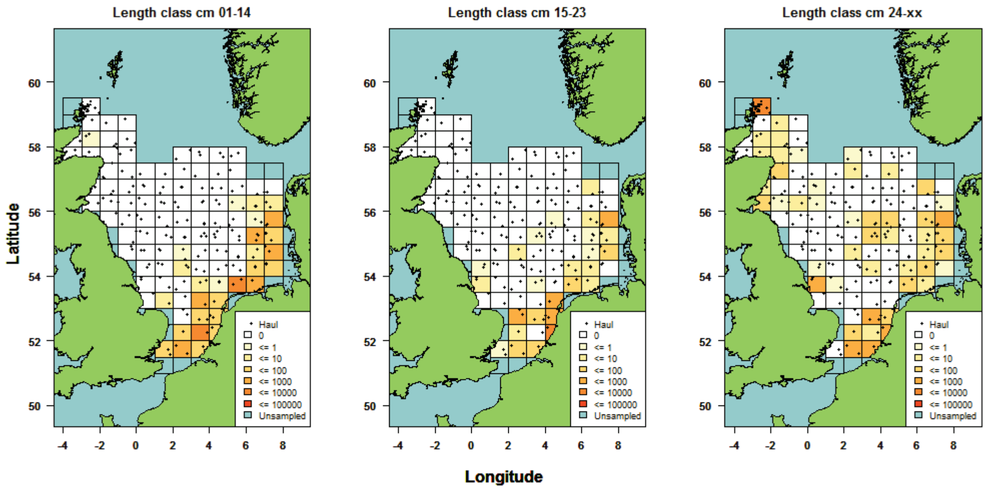
North Sea IBTS catches (cpue) of horse mackerel in 2005

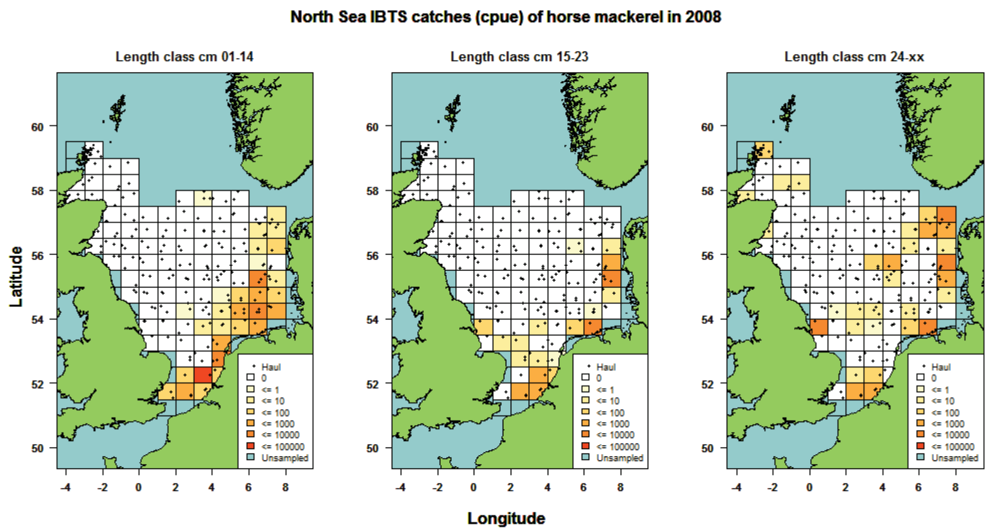


North Sea IBTS catches (cpue) of horse mackerel in 2006



North Sea IBTS catches (cpue) of horse mackerel in 2007




North Sea IBTS catches (cpue) of horse mackerel in 2008
Length class cm 01-14
Length class cm 15-23
Length class cm 24-xx
Latitude
Longitude
Haul
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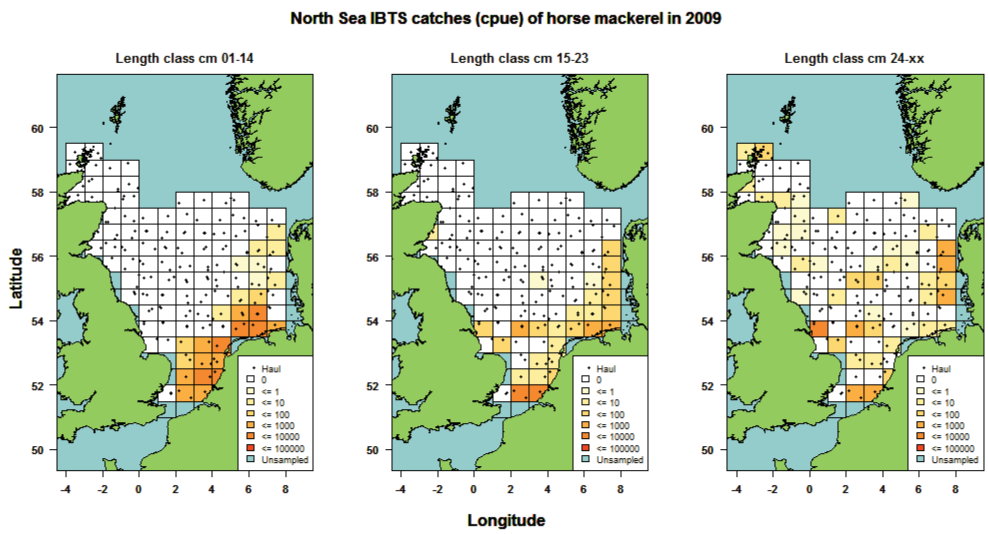
<= 1
<= 10
<= 100
<= 1000
<= 10000
<= 100000
Unsampled


North Sea IBTS catches (cpue) of horse mackerel in 2009
Length class cm 01-14
Length class cm 15-23
Length class cm 24-xx
Latitude
Longitude
Haul
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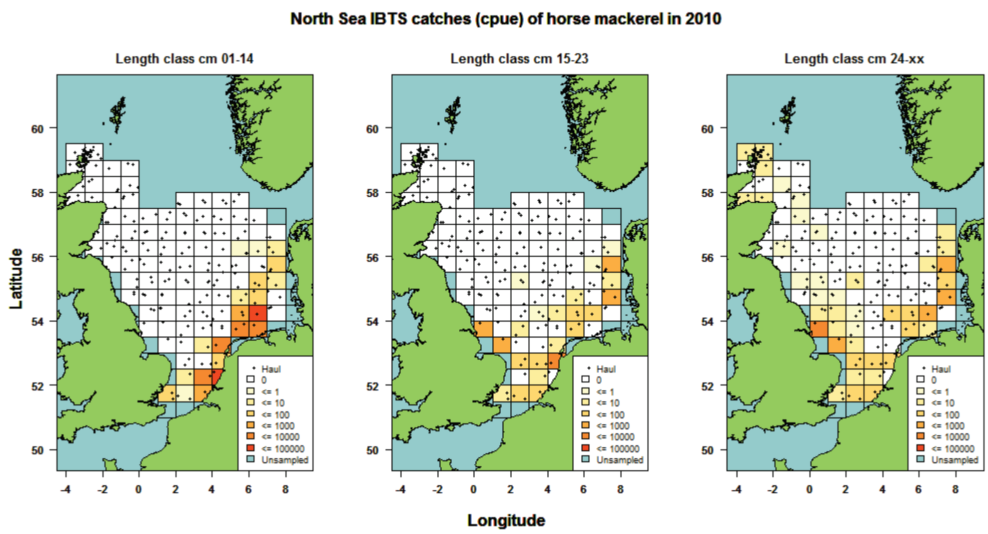
<= 1
<= 10
<= 100
<= 1000
<= 10000
<= 100000
Unsampled


North Sea IBTS catches (cpue) of horse mackerel in 2010
Length class cm 01-14
Length class cm 15-23
Length class cm 24-xx
Latitude
Longitude
Haul
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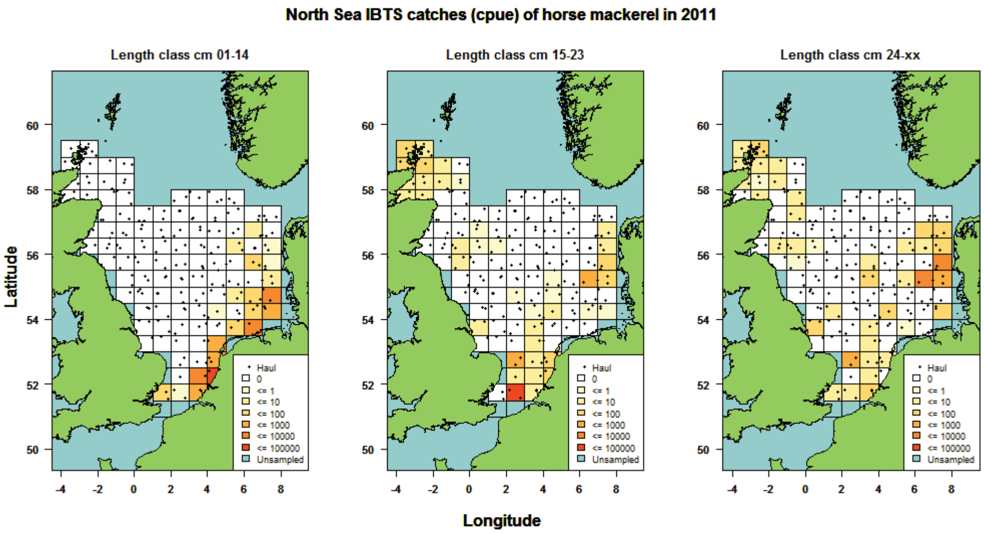
<= 10
<= 100
<= 1000
<= 10000
<= 100000
Unsampled


North Sea IBTS catches (cpue) of horse mackerel in 2011
Length class cm 01-14
Length class cm 15-23
Length class cm 24-xx
Latitude
Longitude
Haul
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<= 10
<= 100
<= 1000
<= 10000
<= 100000
Unsampled

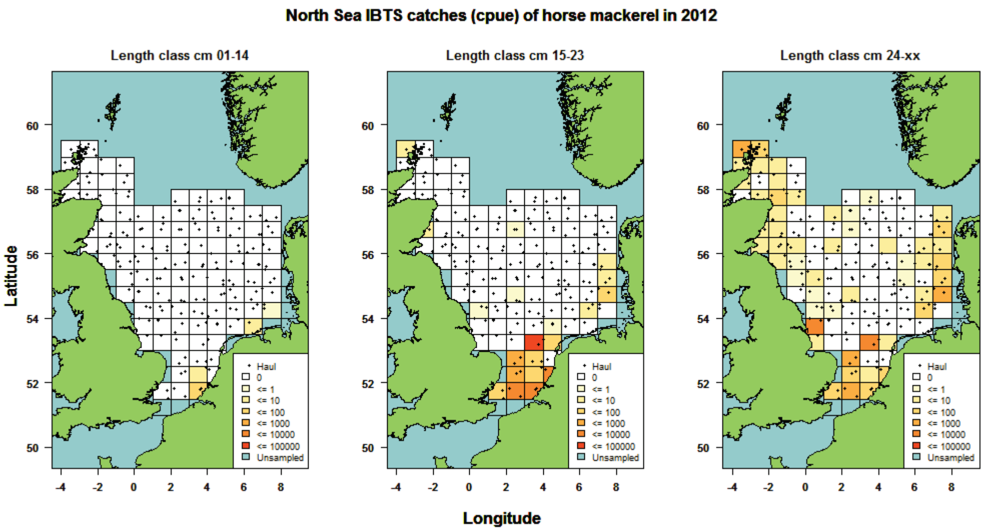
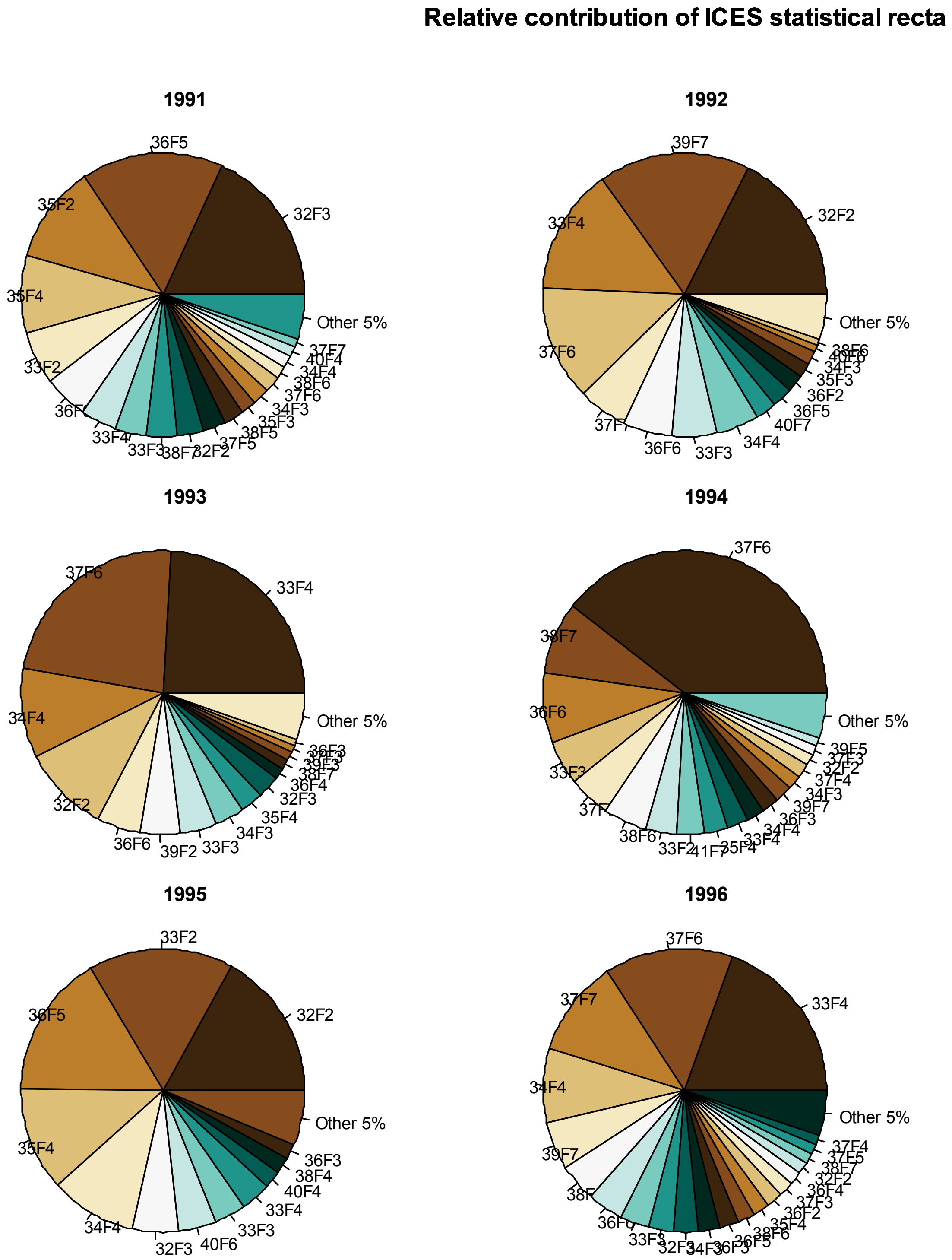

North Sea IBTS catches (cpue) of horse mackerel in 2012
Length class cm 01-14
Length class cm 15-23
Length class cm 24-xx
Latitude
Longitude
Haul
0
<= 1
<= 10
<= 100
<= 1000
<= 10000
<= 100000
Unsampled

Table 1. Summary of cpue by rectangle over the period 1991-2012.

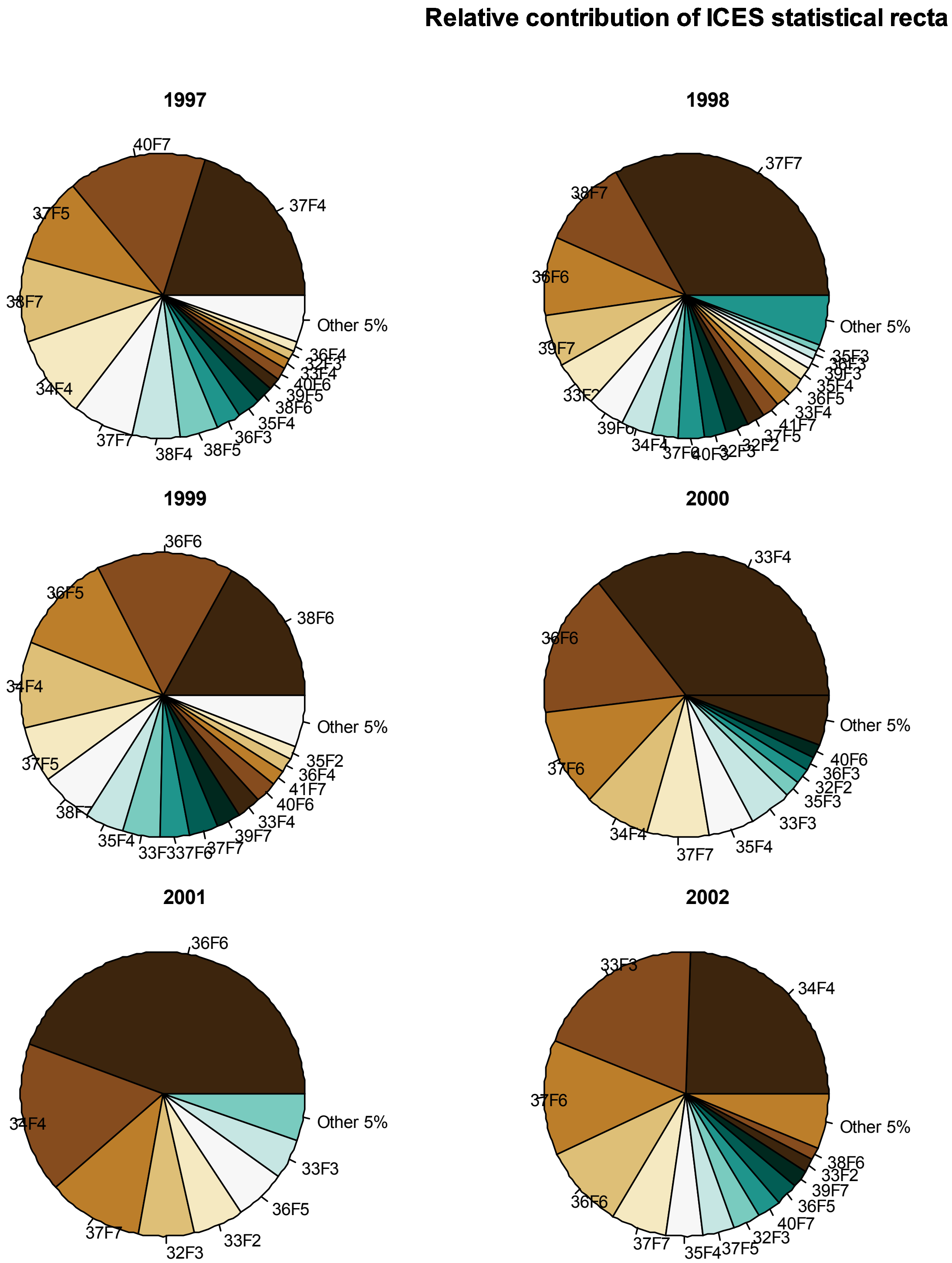
	Mean	*Min*	*Max*	*Variance*	*Zeros*	*NA*
32F1	37.73	0.00	143.00	1.70E+03	1	0
32F2	5713.07	91.50	42081.00	9.76E+07	0	0
32F3	3284.34	112.00	21491.50	2.56E+07	0	0
33F2	2282.11	0.00	19838.00	2.59E+07	1	0
33F3	7412.53	60.00	58374.00	1.50E+08	0	0
33F4	9932.77	40.00	57640.00	2.15E+08	0	1
34F2	293.27	2.00	1724.50	1.94E+05	0	0
34F3	712.02	0.00	3564.50	1.36E+06	1	0
34F4	11359.33	0.00	74264.00	3.54E+08	1	0
35F1	44.56	0.00	706.38	2.24E+04	7	0
35F2	298.23	0.00	2224.00	3.97E+05	5	0
35F3	2358.79	0.00	23809.80	2.98E+07	1	0
35F4	3433.75	52.26	12908.00	1.54E+07	0	0
36F0	679.94	0.00	6010.90	2.25E+06	3	1
36F1	20.31	0.00	304.02	4.33E+03	9	0
36F2	382.51	0.00	4722.00	1.10E+06	6	0
36F3	1170.80	0.00	6950.50	3.21E+06	2	0
36F4	422.84	0.00	2374.00	4.24E+05	2	0
36F5	4691.53	0.00	19820.50	3.44E+07	1	0
36F6	14443.74	8.00	150326.00	1.03E+09	0	1
37F0	10.18	0.00	142.00	1.01E+03	10	1
37F1	16.68	0.00	186.00	1.78E+03	8	1
37F2	102.83	0.00	1348.00	9.87E+04	6	1
37F3	295.72	0.00	1592.00	2.51E+05	1	0
37F4	3302.72	0.00	50570.00	1.21E+08	2	0
37F5	2855.35	0.00	24296.00	4.07E+07	2	0
37F6	11808.48	19.00	58737.50	2.78E+08	0	0
37F7	6898.99	0.00	36810.00	8.73E+07	1	0
38E9	4.04	0.00	55.34	1.42E+02	12	0
38F0	0.30	0.00	1.33	2.32E-01	15	0
38F1	23.80	0.00	185.00	2.82E+03	7	0
38F2	193.91	0.00	1099.00	9.65E+04	3	0
38F3	17.46	0.00	280.50	3.49E+03	9	0
38F4	886.39	0.00	13889.00	8.68E+06	6	0
38F5	990.21	0.00	10617.50	5.55E+06	4	0
38F6	1798.55	2.00	12669.00	9.50E+06	0	0
38F7	2683.72	25.00	23809.50	2.94E+07	0	0
39F0	0.22	0.00	2.00	2.70E-01	17	1
39F1	50.24	0.00	508.67	1.48E+04	12	0
39F2	342.04	0.00	4858.00	1.06E+06	5	0
39F3	181.52	0.00	1053.00	7.87E+04	3	0

39F4	12.03	0.00	82.00	4.52E+02	5	0
39F5	259.30	0.00	3750.00	7.02E+05	7	0
39F6	773.08	0.00	4064.00	1.12E+06	1	0
39F7	4242.50	30.00	41210.50	9.61E+07	0	1
40F1	2.30	0.00	41.67	7.92E+01	16	0
40F2	13.96	0.00	295.50	3.96E+03	15	0
40F3	114.68	0.00	1454.00	9.35E+04	4	0
40F4	234.82	0.00	1805.00	1.73E+05	3	0
40F5	6.27	0.00	44.00	1.41E+02	8	0
40F6	765.96	0.00	3762.00	1.37E+06	1	0
40F7	3942.62	11.00	39551.00	8.00E+07	0	0
41F2	0.32	0.00	4.00	8.23E-01	18	0
41F3	0.27	0.00	3.00	6.60E-01	19	0
41F4	12.46	0.00	234.00	2.46E+03	13	0
41F7	740.63	4.00	4533.50	1.58E+06	0	1
42F3	0.67	0.00	13.00	7.65E+00	19	0
42F4	0.36	0.00	4.00	8.84E-01	17	0
42F5	0.79	0.00	4.00	1.46E+00	12	1
42F6	64.99	0.00	720.00	2.71E+04	3	0
43F4	0.59	0.00	10.00	4.63E+00	19	0
Summary	1837.54	0.00	150326.00	5.25E+07	343	10

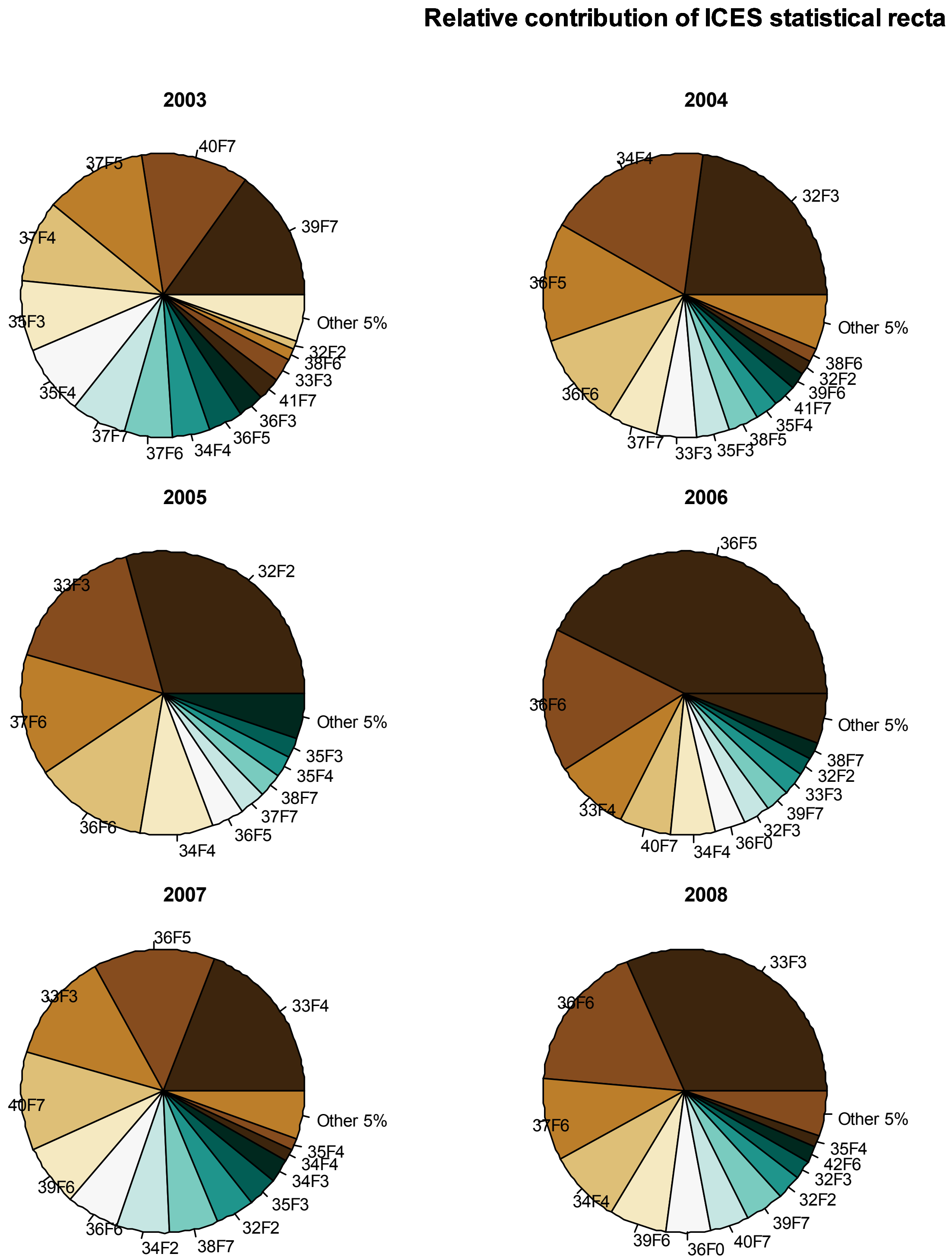
Relative contribution of the 61 individual rectangles in the index area to overall mean cpue per year.



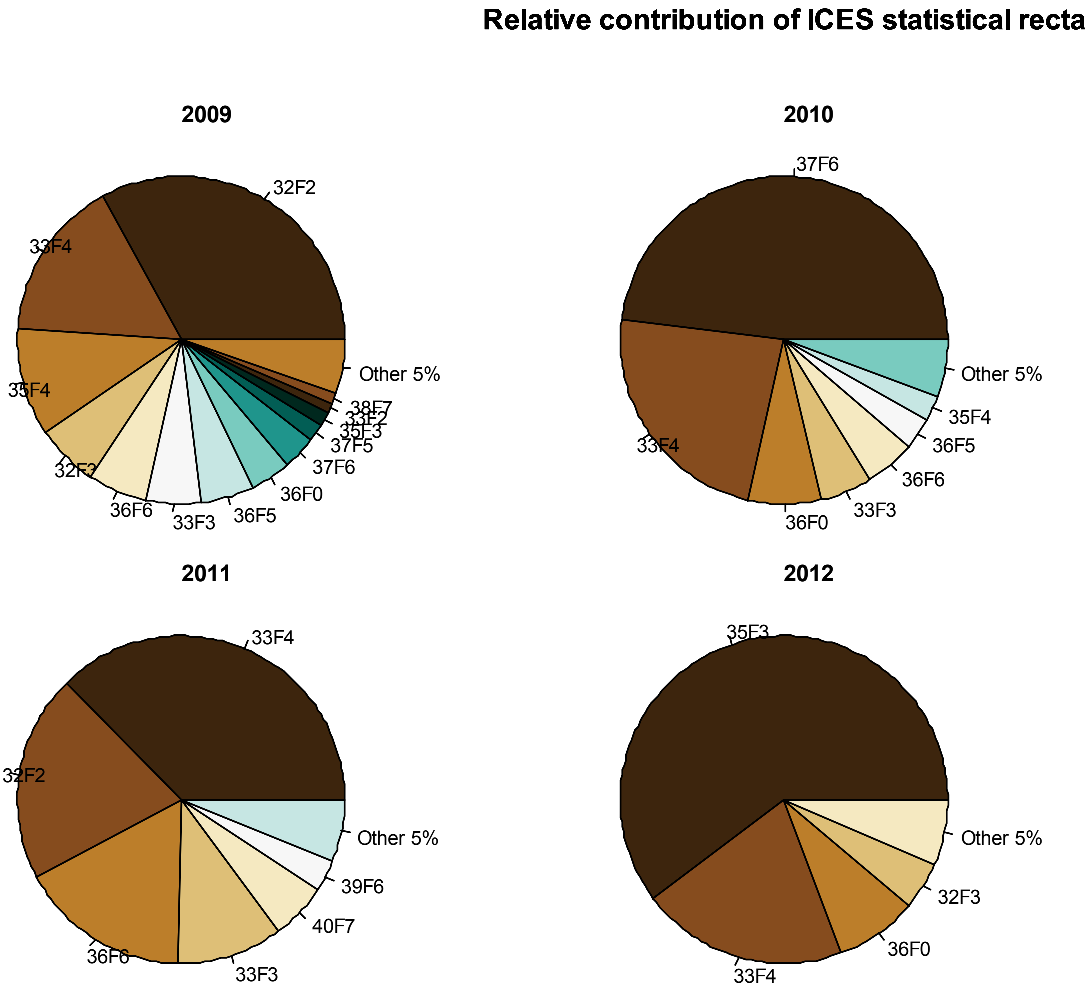
Relative contribution of the 61 individual rectangles in the index area to overall mean cpue per year.

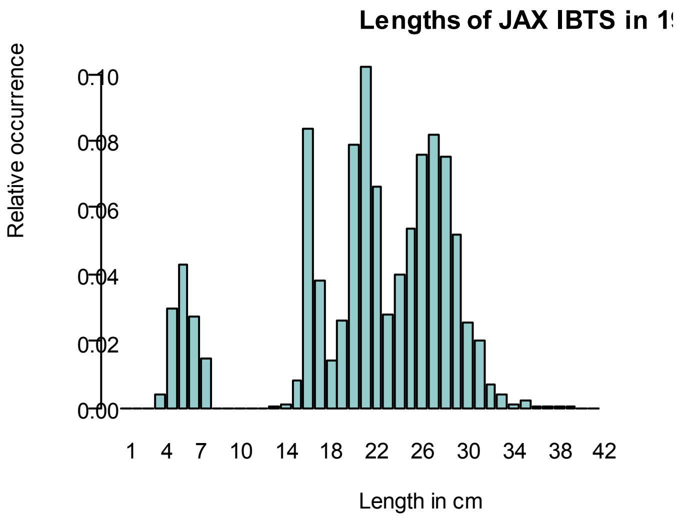


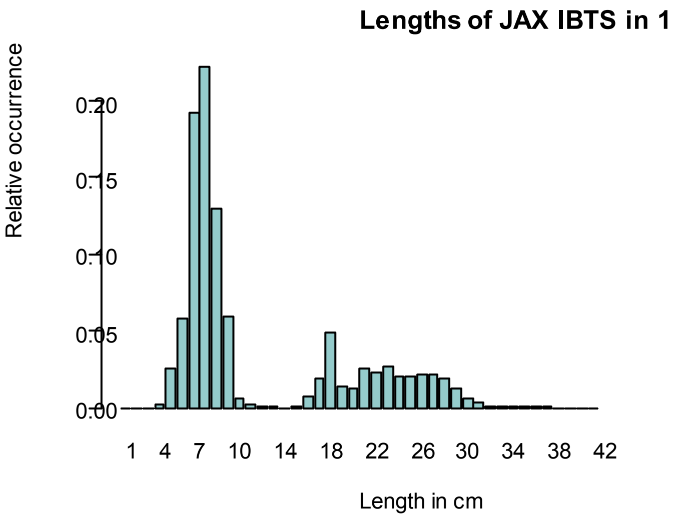
Relative contribution of the 61 individual rectangles in the index area to overall mean cpue per year.



Relative contribution of the 61 individual rectangles in the index area to overall mean cpue per year.




Lengths of JAX IBTS in 1!
Relative occurrence
0.10
0.08
0.06
0.04
0.02
0.00
1 4 7 10 14 18 22 26 30 34 38 42
Length in cm


Lengths of JAX IBTS in 1
Relative occurrence
0.20
0.15
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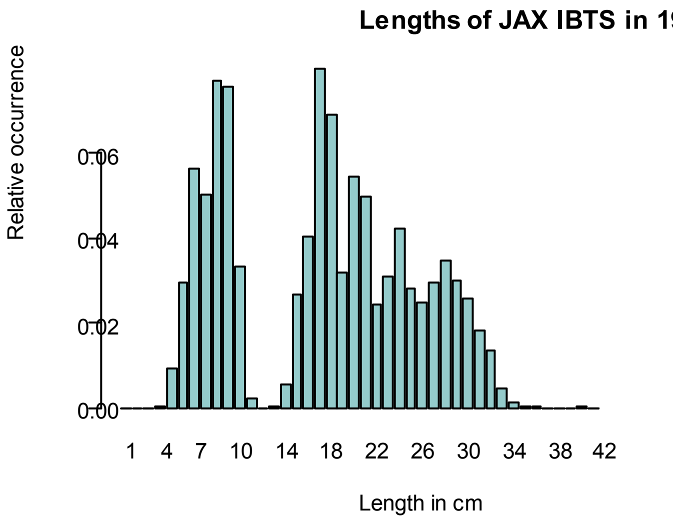
Length in cm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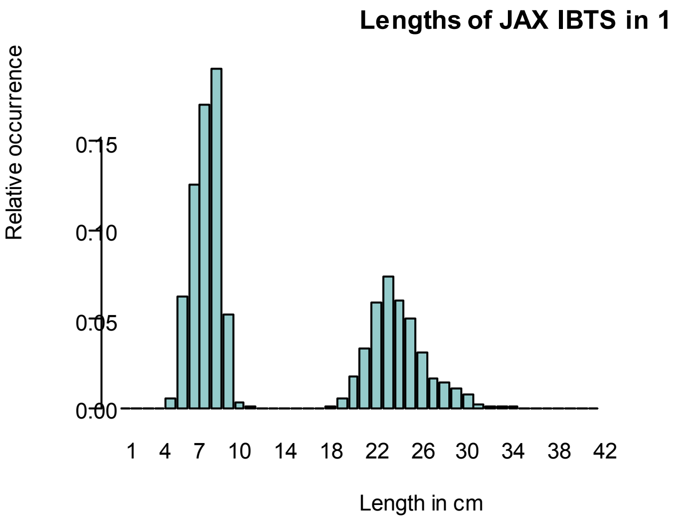
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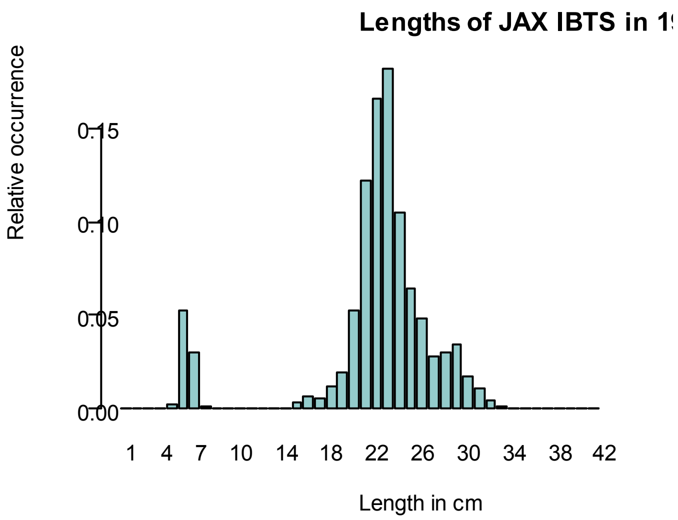
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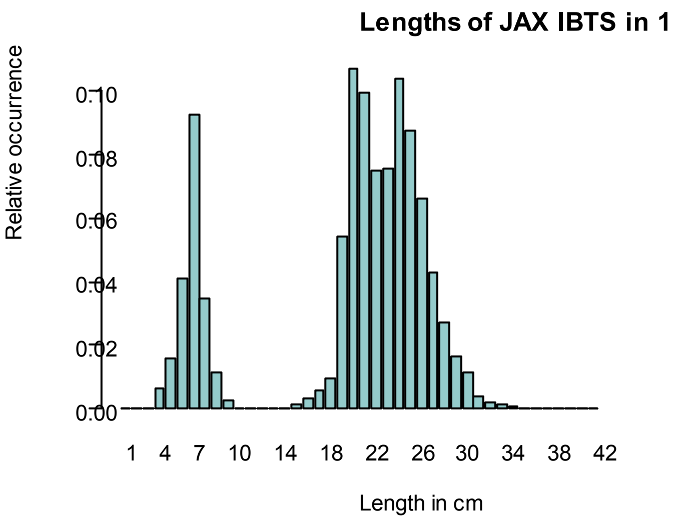
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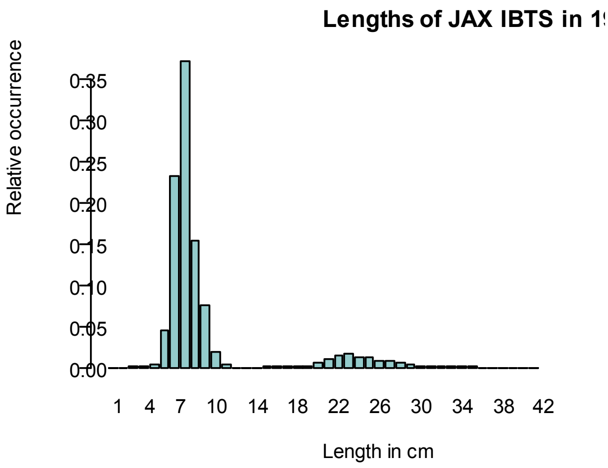
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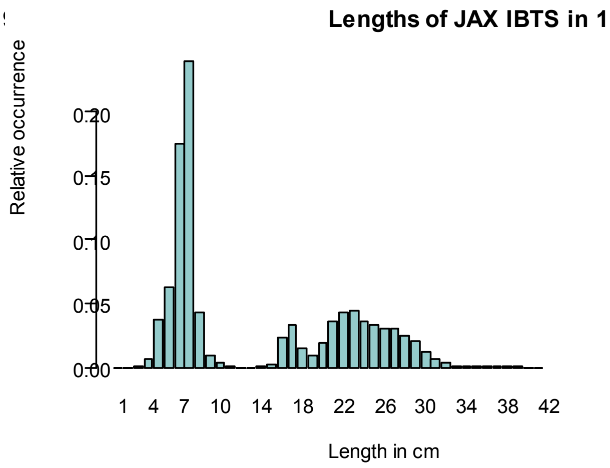
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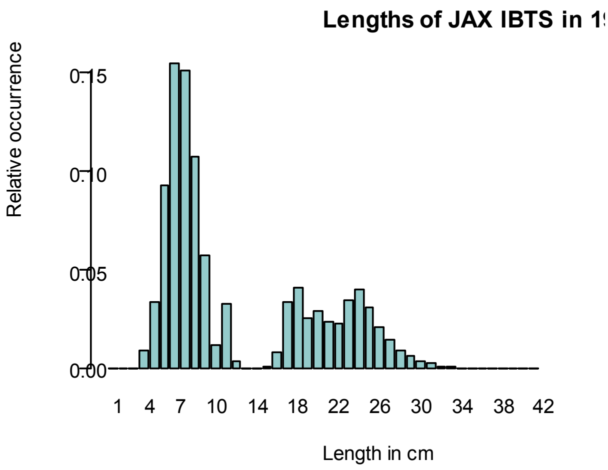
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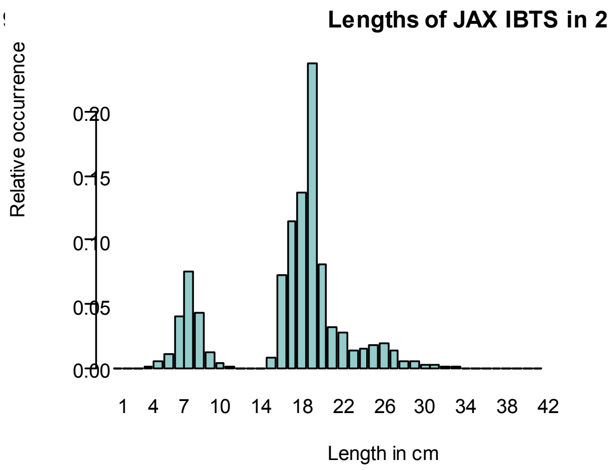
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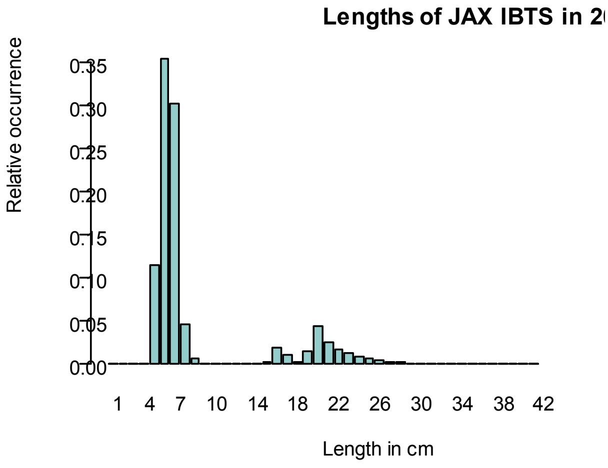
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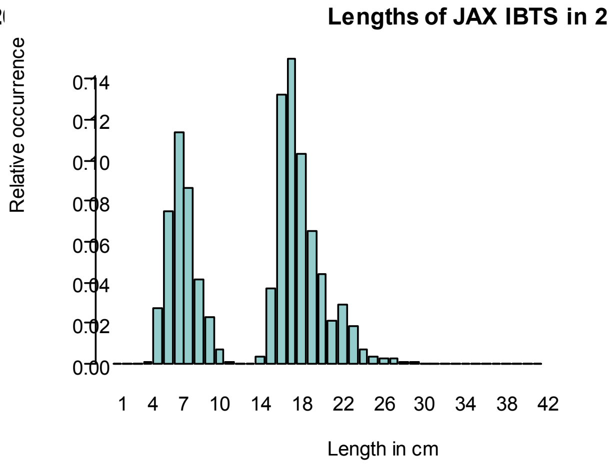
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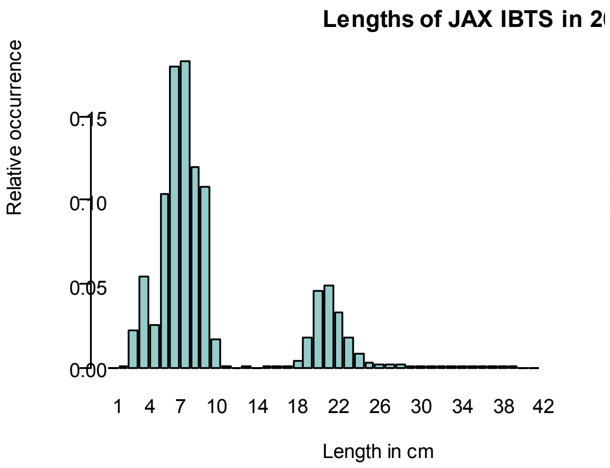
Length in cm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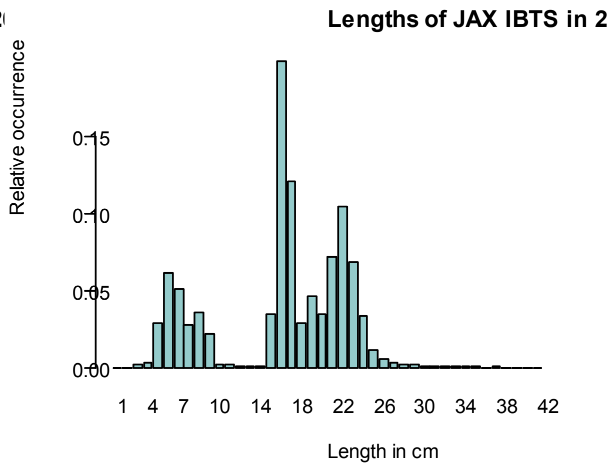
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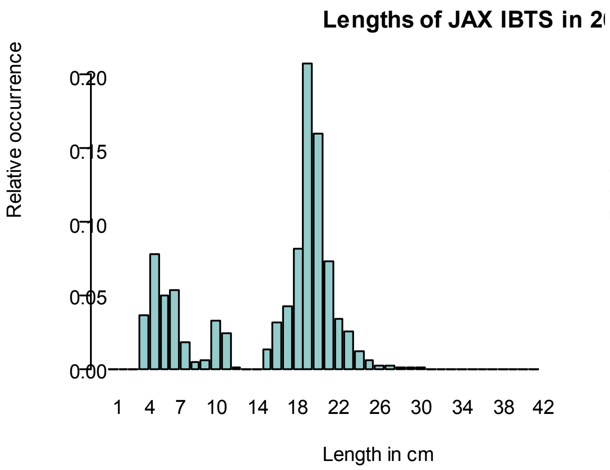
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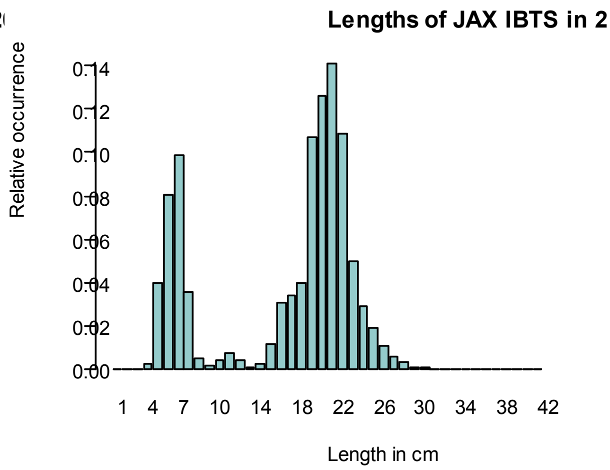
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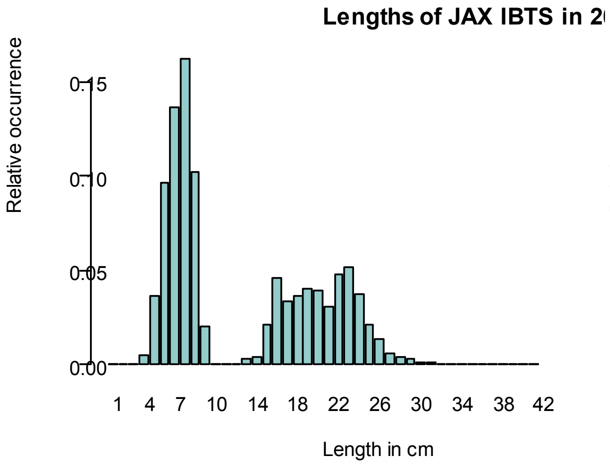
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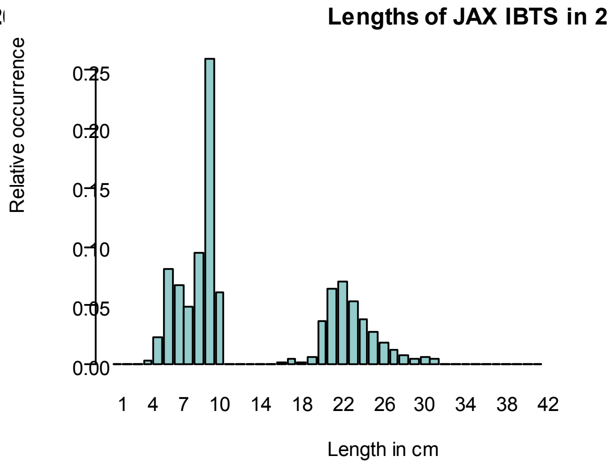
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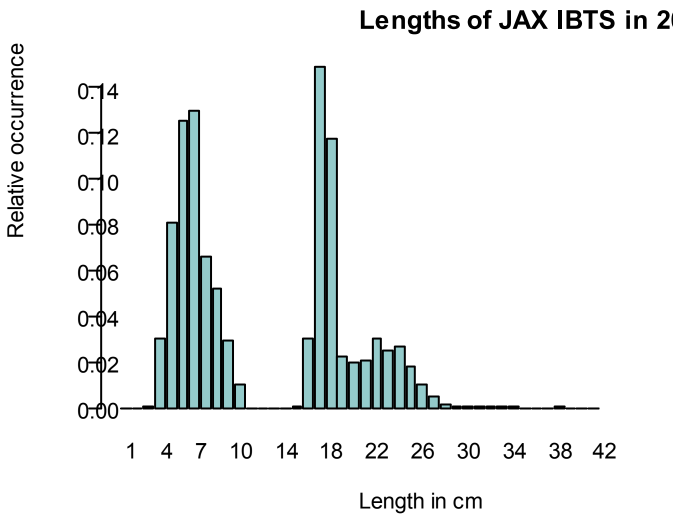
Length in cm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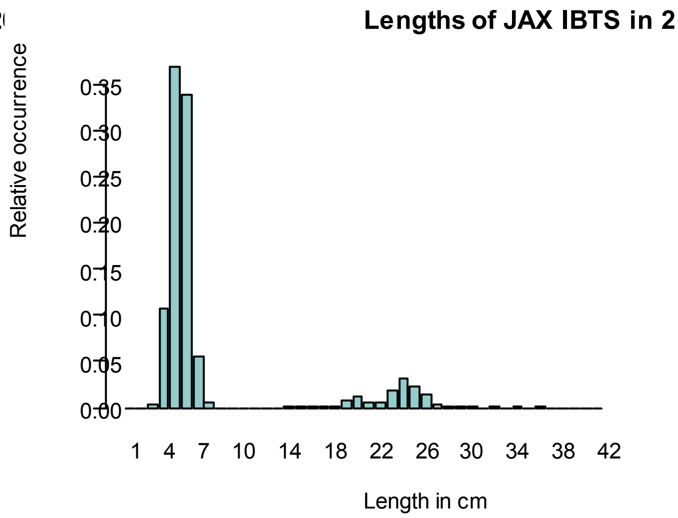
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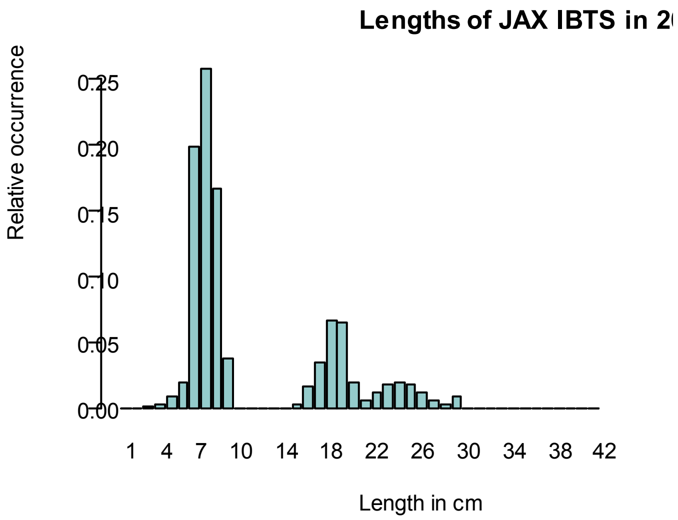
Length in cm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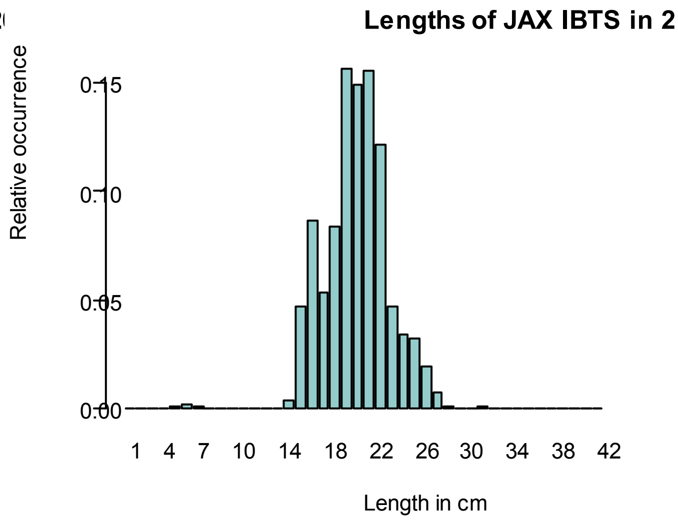
Lengths of JAX IBTS in 2
Relative occurrence
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1 4 7 10 14 18 22 26 30 34 38 42
Length in cm

Working document for the WGWIDE 27/08-02/09/2013, Copenhagen

MULTIDISCIPLINARY ACOUSTIC SURVEY PELACUS0313: PRELIMINARY RESULTS ON FISH ABUNDANCE ESTIMATES AND DISTRIBUTION

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Abstract

The PELACUS 0313 survey was undertook this year on board R/V Miguel Oliver, an oceanographic research stern trawler vessel similar to R/V Thalassa. The survey was characterised by a very bad weather conditions during the first two weeks which did not allow working properly. Moreover, the weather conditions during the rest of survey were almost similar. As a consequence, most of the coastal pelagic fish community remained very close to the coast, thus not accessible to the pelagic gear samplers. (33% of the total acoustic energy –NASC- was unable to be properly allocated into fish species).

Outside the coastal area (>90 m depth) main abundance fish species was mackerel with 380.000 tonnes, corresponding to 1.725 million fish. On the contrary, sardine distribution was scarce, and occurred in small schools (probably as a consequence of the bad weather condition), with only 3.343 tonnes corresponding to 54.0 million fish. Age group 2 was the most abundant, which confirms the high abundance found last year at age group 1 of the 2011 cohort.

Introduction

PELACUS 0313 is the latest of the long-time series (started in 1984) of spring acoustic surveys carried out by the Instituto Español de Oceanografía to monitor pelagic fishery resources in the north and northwest shelf of the Iberian Peninsula (ICES divisions IXa – South Galicia and VIIIc – Cantabrian Sea).

This year the survey was carried out on board R/V Miguel Oliver. This ship, built in 2007, is similar to the Thalassa, a French/Spanish research vessel traditionally used for the survey since

1997 (i.e. a 70 m length stern trawler with diesel-electric power and fixed pitch propeller, within the standard ship underwater radiated noise recommended in ICES CRR 209). Before the cruise, the ship was tested, including acoustic calibration (Foote *et al*., 1987), during a small survey performed in February in Galician waters. Moreover, an additional effort has been undertook by increasing the length of the survey track up to 1000 isobath in order to cover the main distribution area of blue whiting

We present the results on the mackerel, horse mackerel, blue whiting and board fish distribution together with the estimated values of adult fish abundance and biomass obtained in the survey. We also compare the new values with those obtained in previous years.

Material and methods

The methodology was similar to that of the previous surveys (see Iglesias et al. (2010) for further details). Survey design consisted in a grid with systematic parallel transects equally separated by 8 nm and perpendicular to the coastline (Figure 1) with random start, covering the continental shelf from 40 to 1000 m depth and from Portuguese-Spanish border to the Spanish -French one. Acoustic records were obtained during day time together with egg samples from a Continuous Underwater Fish Egg Sampler (CUFES), with an internal water intake located at 5 m depth. CTD casts and plankton and water samples were taken during night time over the same grid in alternating transects. Besides, pelagic trawl hauls were performed in an opportunistic way to provide ground-truthing for acoustic data.

Acoustic equipment consisted in a Simrad EK-60 scientific echosounder (18, 38, 120 and 200 KHz). The elementary distance sampling unit (EDSU) was fixed at 1 nm. Acoustic data were obtained only during daytime at a survey speed of 10 knots. Data were stored in raw format and post-processed using SonarData Echoview software (Myriax Ltd.). The integration values are expressed as nautical area scattering coefficient (NASC) units or s_A values (m^2 nm^{-2}) (MacLennan *et al*., 2002).

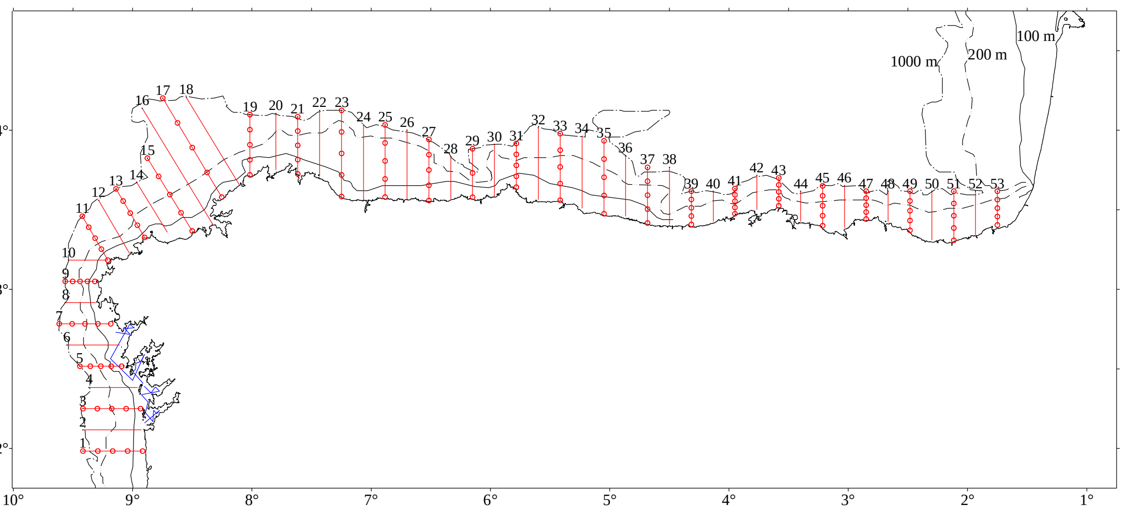


Figure 1 Survey track

Two different pelagic gears were used. Nevertheless, due to the bad weather condition and the specific characteristics of those trawls, hauls were mainly performed in depths higher than 90 m (coastal areas with hard, rough bottoms were inaccessible when fish schools occurred close to the seabed). In general, hauls had a minimum duration of 20 minutes, except those done in areas with high mackerel abundance, where the duration was lower. A two steps method was used to assess the pelagic fish community. First, hauls were classified on account the following criteria: weather condition, gear performance and fish behaviour in front of the trawl derived from the analysis of the net sonar (Simrad FS20/25) records, catch composition in number and length distribution. Each haul was categorised and ranked as follows:

	0	1	2	3
Gear performance Fish behaviour	Crash	Bad geometry Fish escaping	Bad geometry No escaping	God geometry No escaping
Weather conditions	Swell >4 m height Wind >30 knots	Swell: 2 -4 m Wind: 30-20 knots	Swell: 1-2m Wind 20-10 knots	Swell <1 m Wind < 10 knots
Fish number	total fish caught <100	Main species >100 Second species <25	Main species > 100 Second species< 50	Main species > 100 Second species > 50
Fish length distribution	No bell shape	Main species bell shape	Main species bell shape Seconds: almost bell shape	Main species bell shape Seconds: bell shape

These criteria were used as a proxy for ground-truthing. Hauls considered as the best representation of the fish community (i.e. those with higher overall rank on account the four criteria) were used to allocate the backscattering energy got on similar echotraces located in the same area.

Once backscattering energy was allocated, spatial distribution for each species was analysed on account both the NASC values and the length frequency distributions (LFD). These were obtained for all the fish species in the trawl stations (either from the total catch or from a representative random sample of 100-200 fish). For the purpose of acoustic assessment, only those size distributions which were based on a minimum of 30 individuals and which presented a bell shape (normal) distribution were considered. Random subsamples were taken when the total fish caught was higher than 100 specimens. Differences in probability density functions (PDF) were tested using Kolmogorov-Smirnoff (K-S) test. PDF distributions without significant differences were joined, giving a homogenous PDF stratum. Spatial structure and surface (square nautical miles) for each stratum were calculated using EVA and SURFER packages. Fish abundance was calculated with the 38 kHz frequency as recommended at the PGAAM (ICES 2002). Nevertheless, echograms from 18, 120 and 200 kHz frequencies were used to visually discriminate between fish and other scatter-producing objects such as plankton or bubbles, and to distinguish different fish according to the strength of their echo. Also these frequencies have been used to create a mask allowing a better discrimination among fish species and plankton. The threshold used to scrutinize the echograms was –70 dB. Backscattered energy (s_A) was allocated to fish species according to the proportions found at the fishing stations (Nakken and Dommasnes, 1975). For this purpose, the following TS values were used:

Specie	WHB	MAC	HOM	PIL	JAA	BOG	MAS	BOC	SBR	HMM
b_{20}	-67.5	-84.9	-68.7	-72.6	-68.7	-67.0	-68.7	-72.6	-68.7	-68.7

Where WHB is blue whiting; MAC-mackerel; HOM- horse mackerel; PIL-sardine; JAA-blue jack mackerel; BOG-bogue; MAS-chub mackerel; BOC-board fish; SBR-sea breams and similar specie; and HMM-mediterranean horse mackerel. When possible, direct allocation was also done. Biomass estimation was done on each strata (polygon) using the arithmetic mean of the backscattering energy (NASC, s_A) attributed to each fish species and the surface expressed in square nautical miles.

For each main specie, a centre of gravity (Woillez et al. 2007) was calculated as a weighted average of each sample location (allocated NASC value as weighting factor). Due to the particular topography of the NW Spanish area, instead longitude and latitude, we have used depth and a new variable called "distance from the origin" calculated as follows:

- Locations below 43º10 N: distance is calculated as (Lat-41.5)*60, being *Lat* the latitude of the middle point of any particular EDSU within this region.
- Location between 43º10' N and 8ºW (i.e. NW corner): distance is calculated as (I.Lat-41.5)*60, being *I.Lat* the latitude at which a normal straight line from middle point of any particular EDSU within this region intercepts a line defined by the following geographical coordinates: 43º11N-9º12.50'W and 43º39.50'N-8º06'W.
- Location between 8ºW and the Spanish-French border: distance is calculated as 129.5+(Lon+5.8755324052)*60, being *Lon* the corrected longitude (longitude multiplied by the cosine of 43.50) of the middle point of any particular EDSU within this region.

Besides each fish was measured and weighed to obtain a length-weight relationship. Otoliths were also extracted from anchovy, sardine, horse mackerel, blue whiting and mackerel in order to estimate age and to obtain the age-length key (ALK) for each species for each area.

Results

A total of 3642 nautical miles were steamed, 1080 of them corresponding to the survey track. In IXa-N, due to the bad weather conditions, half of the transects were not surveyed and the rest, together with those located in the VIIIc-W Sub-Division, have had to be sternway steamed to avoid bubbles sweep down. This can cause attenuation of sound transmission and reception of backscattering energy, thus an underestimation of the fish population. This phenomenon still persisted and, therefore, acoustic records gathered in the western areas were filtered to remove those pings with a large amount of attenuation. For each ping of the 38 kHz frequency, Sv were tested for deviations (a total of 500 samples-Sv values- in the echogram for each ping). If the maximum value of Sv achieved in the water column was lower than -70dB, we assumed that an important attenuation occurred and therefore the ping was removed. This was applied until the 22nd March when main swell and wind directions were either stern or bow way. The number of pings removed is shown in the following table

Day	Total ping number	Pings removed	%
08/03/13	35388	783	2.21
09/03/13	64659	1175	1.82
10/03/13	22408	356	1.59
11/03/13	27790	1274	4.58
12/03/13	44615	935	2.10
13/03/13	47876	955	1.99
14/03/13	26872	123	0.46
15/03/13	32980	217	0.66
16/03/13	55257	451	0.82
17/03/13	49619	501	1.01
18/03/13	33884	1516	4.47
19/03/13	40805	505	1.24
21/03/13	93009	2140	2.30
22/03/13	61923	394	0.64

Sternway steaming has considerable reduced the number of ping removed. However, the coverage in the continental shelf was reduced by a 50%.

A total of 45 fishing station were performed, one of them was removed. Figure 2a-d shows the location and the value for each ground truthing criteria (from 0 to 3).

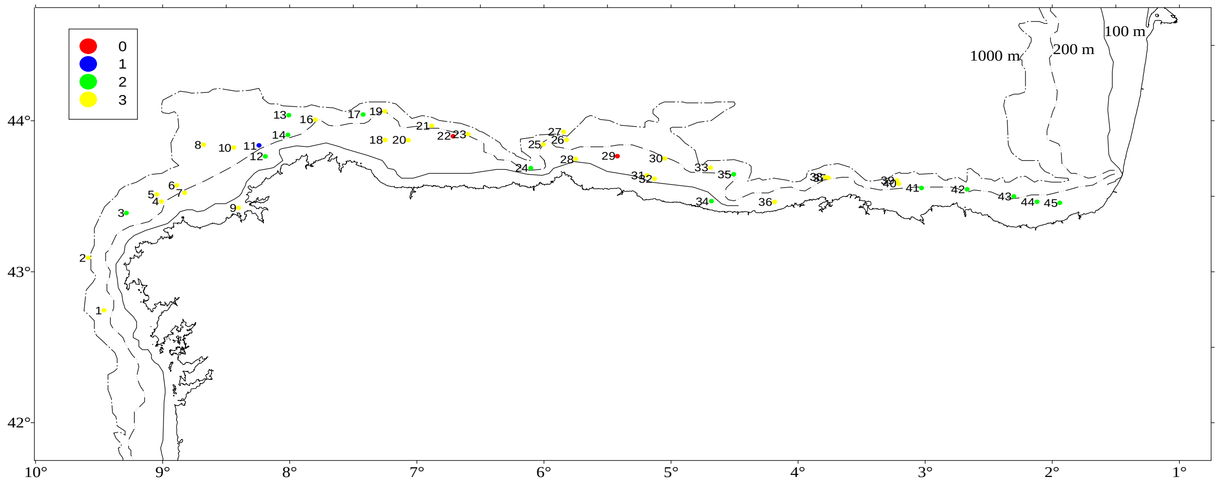


Figure 2a: Fishing station and colour system according with the Gear performance and fish behaviour criteria

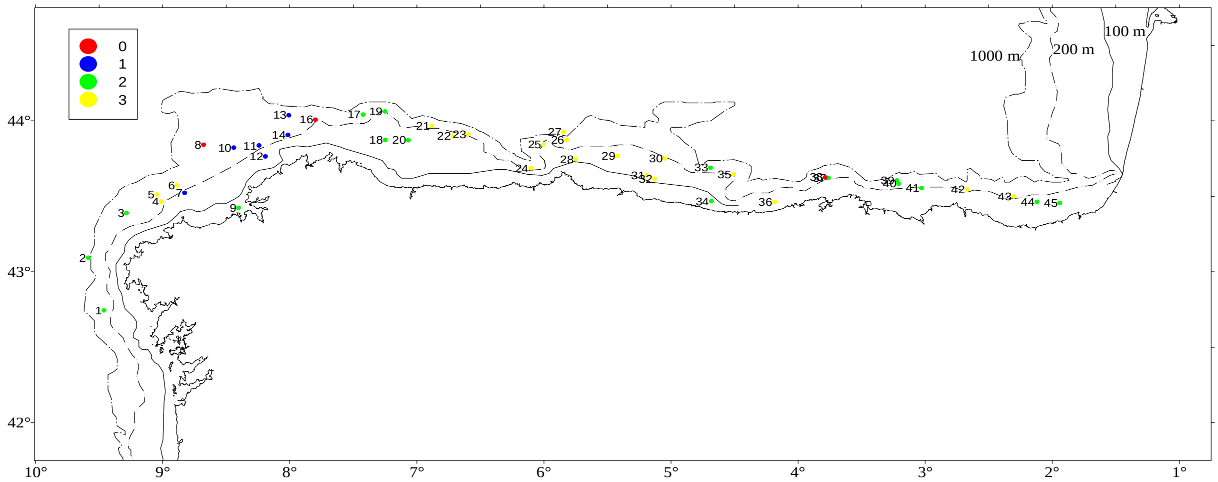


Figure 2b: Id according with the Weather condition criteria

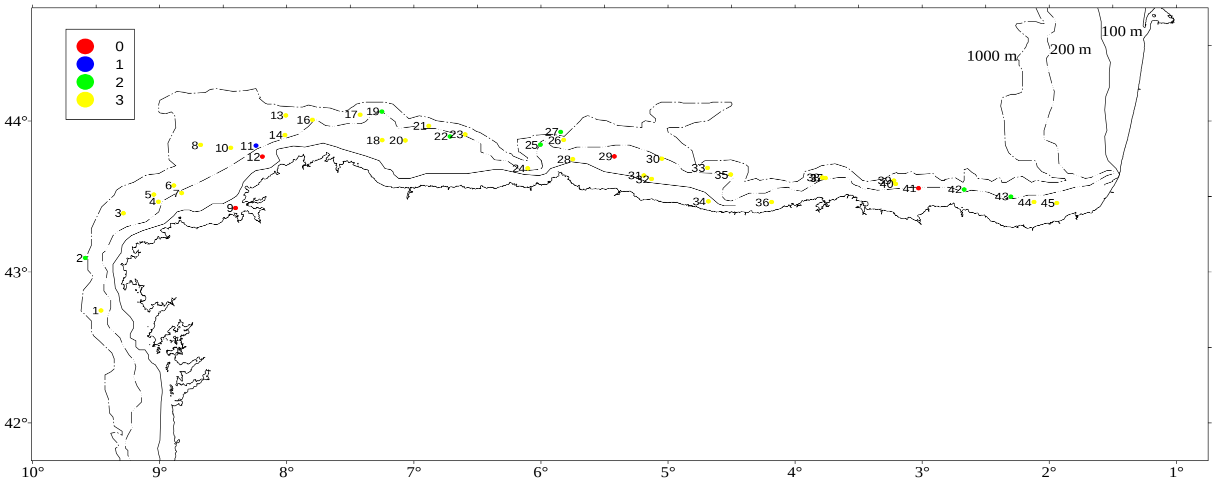


Figure 2c: Id according with the Fish number criteria

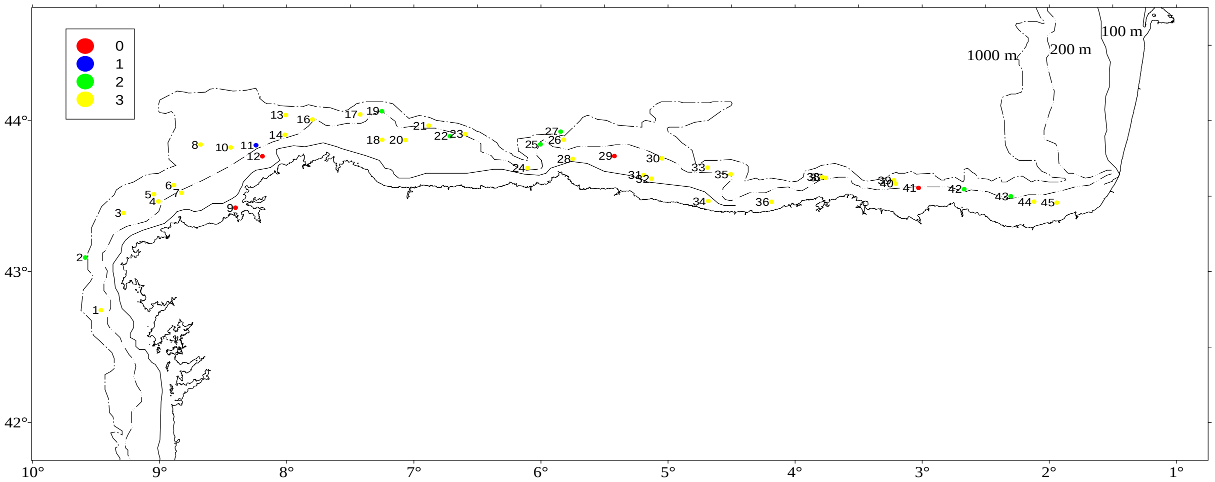


Figure 2d: Id according with the Fish length distribution criteria

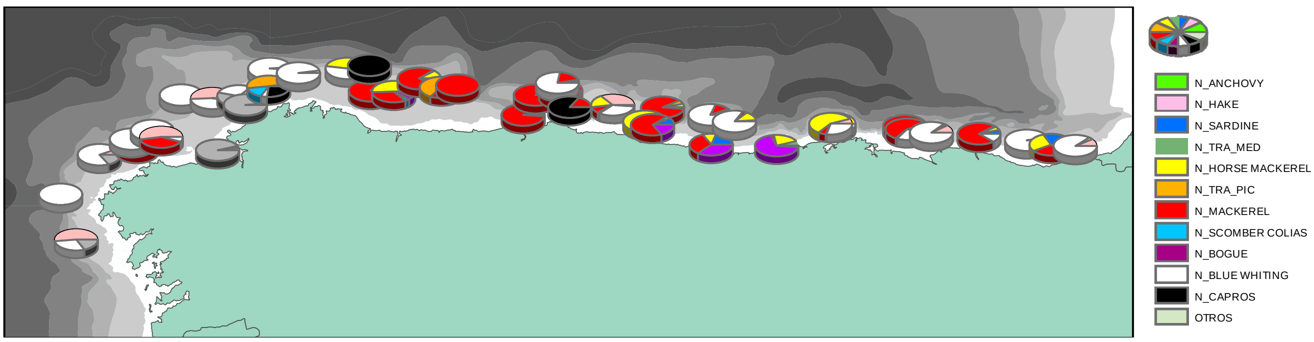


Figure 2e: Fish proportion at each fishing station

On the other hand, 381 CUFES stations, comprising 3 nautical miles each were taken, as shown in figure 3.

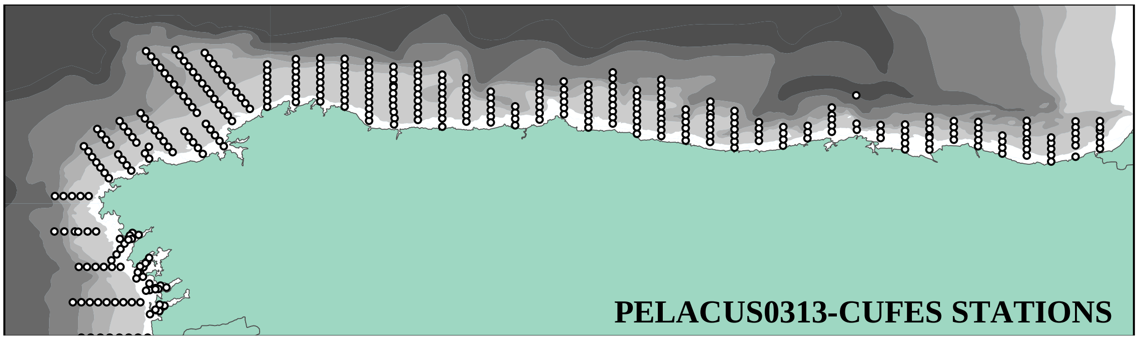


Figure 3. PELACUS0313 CUFES stations.

Acoustic

A total of 105.384,67 s_A were attributed to fish species. Table 1 shows the fishing station used to allocate backscattering energy when echotraces were similar to those found around these fishing station.

Table 3: Fishing station used for backscattering energy allocation and transects

Fishing station	Transects
PE02	RA01, RA03, RA05, RA07, RA09
PE03	RA11
PE04	RA12, RA13, RA14, RA15, RA16, RA17
PE05	RA12, RA13
PE06	RA14
PE08	RA16, RA17, RA18
PE13	RA19
PE14	RA19, RA20
PE16	RA21
PE17	RA22, RA25
PE18	RA21, RA22, RA23, RA24
PE19	RA23
PE20	RA24
PE21	RA25
PE22	RA26
PE23	RA26, RA27
PE24	RA29
PE25	RA30
PE26	RA31
PE27	RA31
PE28	RA30, RA31
PE30	RA34, RA35, RA37
PE31	RA33, RA34
PE31	RA35
PE32	RA33, RA34, RA35, RA36, RA37
PE33	RA36, RA37
PE34	RA36, RA37, RA38, RA39, RA40
PE35	RA38, RA39
PE36	RA39, RA40
PE37	RA42, RA43
PE38	RA40, RA41, RA42, RA43
PE39	RA44, RA45, RA46, RA47

PE40	RA44, RA45, RA46, RA47
PE42	RA48
PE43	RA48, RA48, RA49, RA50
PE44	RA49, RA50, RA51, RA52, RA53

Due to the bad weather conditions and gear performance limitations to properly work close to the coast with hard and rough sea bed, a 33% of the total backscattering energy (34.720,97 s_A) was no possible to allocate and therefore remained as unallocated. Table 2 shows the backscattering energy distributed by species and ICES subdivision, either by direct allocation (DA) or through the proportion found at de fishing stations (Fst). Direct assignation was feasible accounting for its special acoustic properties, morphology and geographical characteristics for some sardine schools, board fish, horse mackerel and sardine. In IXa-N the 55% of the energy was unallocated (4% of the total energy); in VIIIc-W, the 37 % (5% of the total); in VIIIc-Ew, the 28% (18 % of the total energy); and in VIIIc-Ee, the 41% (6% of the total energy).

Table 4: Backscattering energy (s_A) allocated by species, both by direct allocation (DA) and by the fish proportion found at the ground-truth fishing stations, and by ICES Sub-Division (WHB-blue whiting; MAC-mackerel; HOM- horse mackerel; PIL-sardine; JAA-blue jack mackerel; BOG-bogue; MAS-chub mackerel; BOC-board fish; SBR-sea breams and similar specie; HMM-mediterranean horse mackerel; NEI-unallocated NASC)

		WHB	MAC	HOM	PIL	JAA	BOG	MAS	BOC	SBR	HMM	NEI	total
IXa	DA			382.8	1897.3							4188.0	6468.1
	Fst	1214.3		0.7									1215.0
VIIIc-W	DA		28.6						737.1			5536.4	6302.1
	Fst	6768.5	1419.1	122.9	4.8	120.6		65.4	5.6	0.4			8507.4
VIIIc-Ew	DA		3424.1		749.0				2315.2			18975.9	25464.1
	Fst	16207.1	2631.8	8213.8	598.6	2131.4	9647.3	921.9	2182.3	64.6	29.3		42628.1
VIIIc-Ee	DA		577.2									6020.6	6597.9
	Fst	3270.9	579.2	3203.3	839.2	45.1	202.5	61.5	0.3				8202.0
Total	DA		4029.9	382.8	2646.2	0.0	0.0	0.0	3052.3			34721.0	44832.2
	Fst	27460.9	4630.0	11540.8	1442.6	2297.0	9849.8	1048.8	2188.2	65.0	29.3		60552.5
Total		27460.9	8659.9	11923.6	4088.8	2297.0	9849.8	1048.8	5240.4	65.0	29.3	34721.0	105384.7

Spatial patterns

Table 5 and figure 4 summarizes the spatial indices of the main fish species.

Table 5: Centre of gravity according to the weighting average calculated using Distance to the Origin (D.O.; expressed in nautical miles) and depth (DEPTH, expressed in meters) together with its standard deviation, and the conversion to geographical position of the distance to the origin (Lat/Lon). (WHB-blue whiting; MAC-mackerel; HOM- horse mackerel; PIL-sardine; JAA-blue jack mackerel; BOG-bogue; MAS-chub mackerel; BOC-board fish; MAC-Juvenile (<30 cm length); MAC-Adult (>30 cm length))

	Specie									
	WHB	**MAC**	**HOM**	**PIL**	**JAA**	**BOG**	**MAS**	**BOC**	**MAC-j**	**MAC-a**
D.O.	170.87	22.04	264.34	204.98	160.35	258.35	167.51	176.99	152.96	257.09
s.d.	85.32	74.78	90.97	129.71	39.79	65.51	54.95	29.33	43.68	61.74
Depth	191.93	184.96	165.93	144.94	152.22	160.02	162.75	161.05	159.93	197.66
s.d.	85.69	135.85	81.56	141.71	32.36	102.97	53.34	32.53	114.98	147.91
Lat/Lon	7.15	5.97	5	4.6	7.4	5.142	7.2	7.0	7.57	5.137

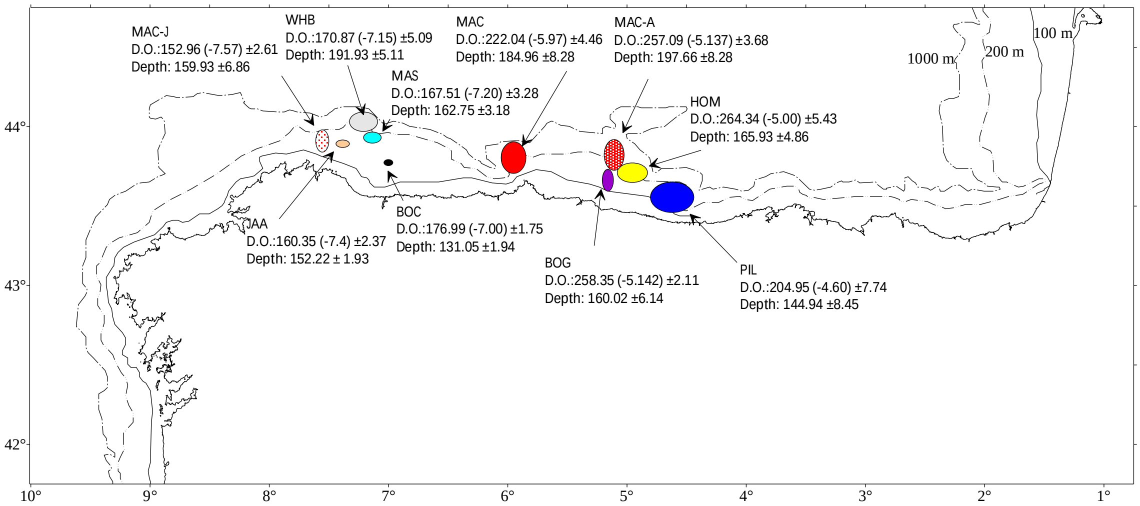


Figure 4 Centre of gravity of NASC distribution for the main fish species. Ellipses are proportional to the confidence intervals for both variables, Distance to the Origin (D.O.) and Depth

Excluding mackerel without split into juvenile and adults, it seems that there were two main distribution areas, one located eastward of the Cape Ortegal/Estaca de Bares , with some influence of Atlantic waters (juvenile mackerel, blue whiting, blue jack mackerel, chub mackerel and board fish) and other located between Lastres and Llanes canyons (sardine, horse mackerel, bogue and mackerel). While sardine had the widest distribution area, both in depth distribution and along the coast, board fish and blue jack mackerel were mainly distributed in the center part of the surveyed area. The coincidence in the distribution area of sardine mackerel, horse mackerel and bogue will be deeply discussed further.

Mackerel distribution and assessment

Mackerel was the most important fish species and was present in 38 of the 44 valid fishing station performed during the survey (a total of 75656 specimen were caught). Almost no mackerel was found in IXa-N, being concentrated in VIIIc. Nevertheless, there was two different areas, the western area where juvenile were predominant (between 100 and 73% of the total number) and the eastern were adults were predominant (97%). Accordingly, the distribution area was divided in four main region. In VIIIc-East mean length was 26 cm without statistical differences among length distribution (K-S test), although the westernmost area had higher density. On the contrary, in VIIIc-West, there were significant differences among length distributions, with a predominant juvenile area with 29 cm as mean length in the westernmost area (Bay of Masma) and the adult area with 35 cm as mean length, without significant differences among length distributions (figure 5)

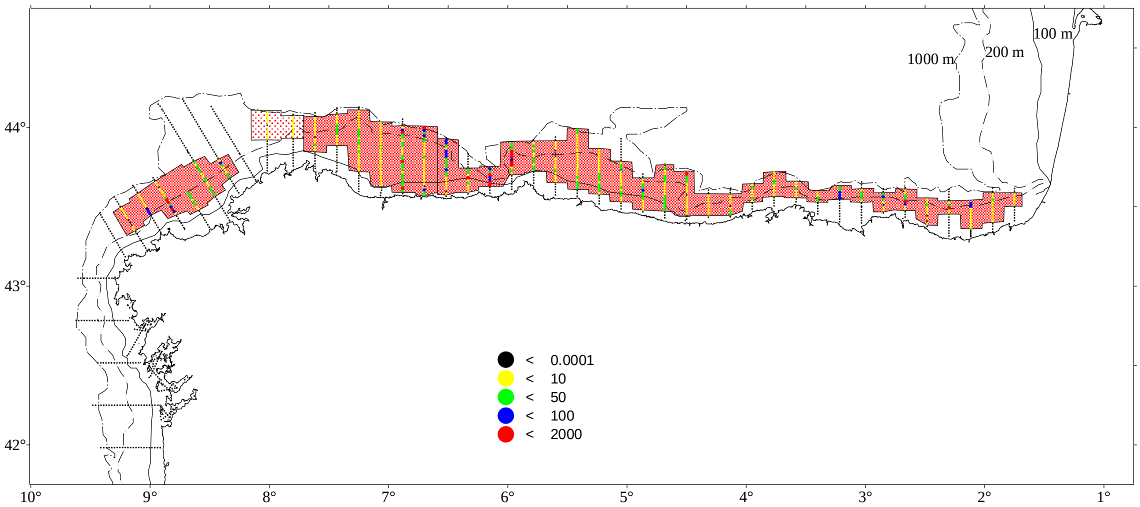


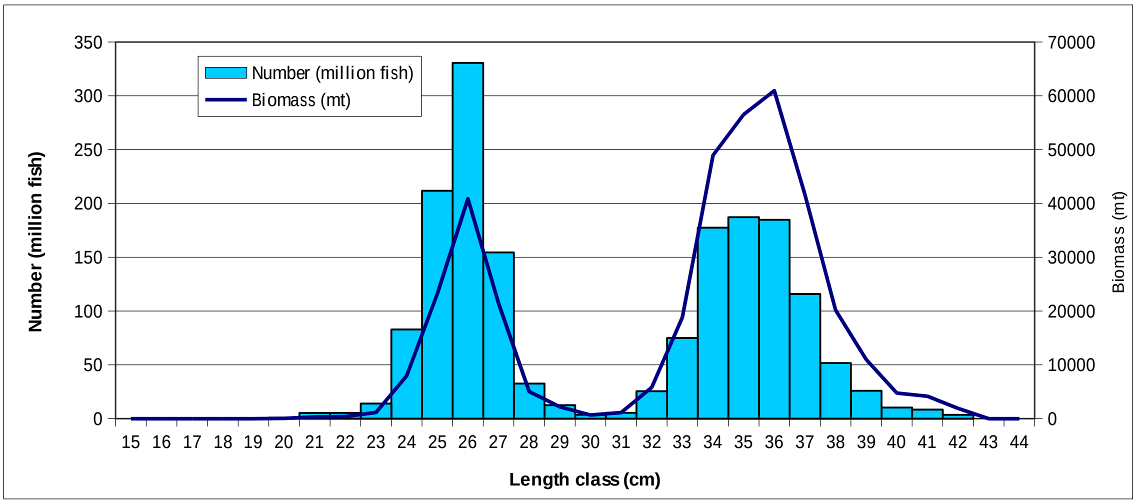
Figure 5. Mackerel: spatial distribution PELACUS0313 cruise. Polygons are drawn to encompass the observed echoes, and polygon colour indicates the mean integrated energy in m^2 within each polygon (>0-10; and 10-100 s_A)

Table 6 shows the mackerel assessment. 379149 mt has been estimated, corresponding to 1.725 million fish. The bulk of the distribution occurred in the central part of the Cantabrian Sea.

Table 6 Mackerel acoustic assessment

Zone	Area	No	Mean	$\hat{\sigma}^2$	Model	v*	nugget/model	Area	Fishing st.	PDF	No (million fish)	Biomass (tonnes)
VIIIc-W	Artabro	67	21.61	1599.73	600+sph(1000,7)	33.63	26.66%	606	P04-P07-P16	ST01	463	58008
	Estaca	20	0.18	0.35	na	na	na	195	P04-P07-P16	ST01	1	155
	Total	***87***	***17***					***801***			***464***	***58163***
VIIIc-E	Masma	128	15.00	1049.07	600+sph(600,12)	450.1666	99.00%	1004	P18-P20-P22	ST02	452	72810
	Cantabrian	241	18.30	1180.45	800+sph(500,20)	373.9187	70.00%	2278	P32-P33-P34-P35-P36-P37-P38-P39-P40-P42-P44	ST03	809	248176
	Total	***369***	***17***					***3282***			***1261***	***320986***
	Total VIIIc	***456***	***17***					***4083***			***1725***	***379149***
	Total Spain	***456***	***17***					***4083***			***1725***	***379149***

Figure 5. Mackerel length distribution in both number and biomass during the PELACUS0313 survey.

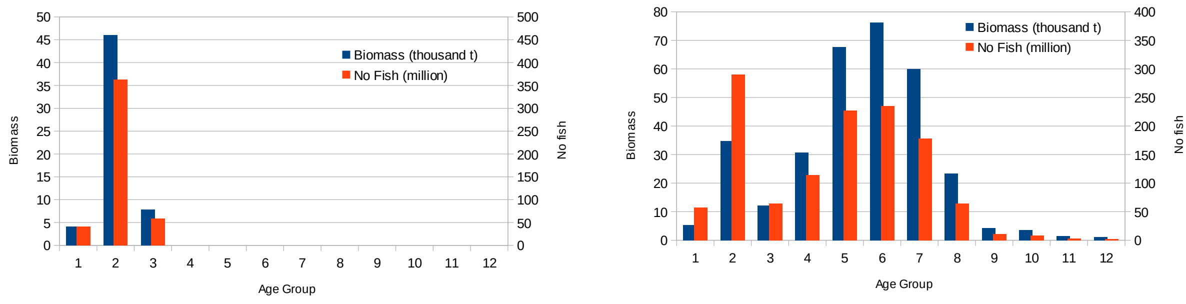


Age groups 2 and 6 were the most abundance (table 7) giving a bimodal distribution as shown in figure 5. Besides, the strength of the age group 2 agreed with the high abundance of age group 1 found in the last year survey (57% of the total fish abundance in 2011).

Table 7. Mackerel abundance in number (thousand fish) and biomass (tons) by age group and ICES sub-area in PELACUS0313.

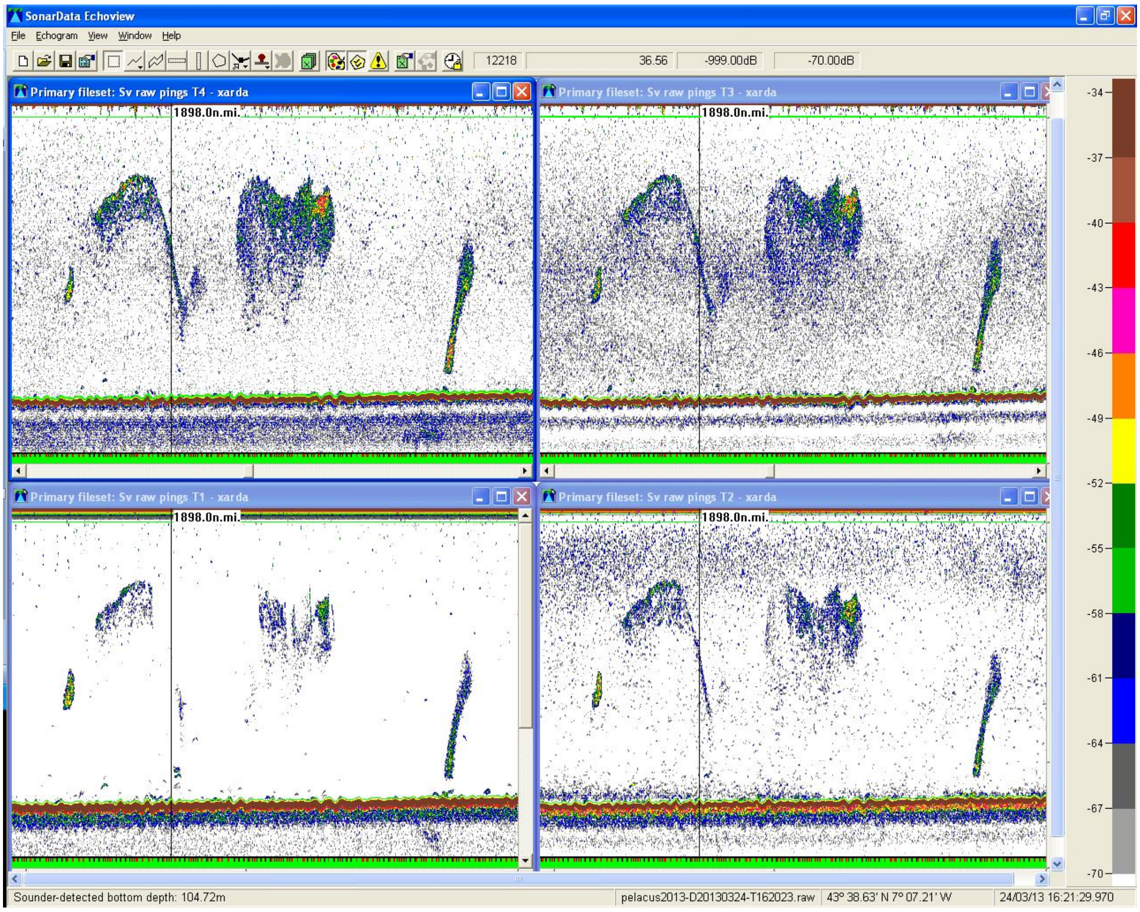
	AGE GROUPS													
Length	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Total**	**No fish (milli**
10														
11														
12														
13														
14														
15														
16														
17														
18														
19														
20														
21														
22	0.40												0.40	5
23	0.89	0.26											1.16	14
24	6.50	1.46											7.96	83
25	0.96	21.28	0.93										23.17	211
26	0.71	34.55	5.55										40.80	330
27		16.39	5.02										21.41	154
28		4.50	0.53										5.03	33
29		2.11	0.08										2.20	12
30		0.22	0.22	0.22									0.67	4
31			0.23	0.68	0.23								1.13	5
32			0.53	3.71	1.32	0.26							5.82	26
33			2.94	7.06	6.77	1.18	0.59	0.29					18.83	75
34			1.97	11.17	18.73	11.17	5.26	0.66					48.95	177
35			1.42	4.55	18.75	17.33	11.65	2.27	0.57				56.53	187
36			0.60	2.70	14.41	21.32	16.51	4.50	0.90				60.95	185
37				0.34	5.08	17.26	12.86	5.08	0.68	0.34			41.62	116
38				0.33	1.30	5.53	7.16	5.21	0.33	0.33			20.17	52
39					0.76	0.76	4.54	3.03	0.38	1.14	0.38		10.98	26
40					0.37	0.73	0.73	0.73	0.73	0.73	0.37	0.37	4.76	10
41						0.42	0.42	1.25	0.42	0.83	0.42	0.42	4.17	8
42						0.27	0.27	0.27	0.27	0.27	0.27	0.27	1.91	4
43														
44														
Biomass (thousand t)	9	81	20	31	68	76	60	23	4	4	1	1	379	1718
%	2.50	21.33	5.29	8.12	17.88	20.13	15.84	6.15	1.13	0.96	0.38	0.28		
M. weight	93.04	119.14	152.37	267.55	296.01	322.29	335.34	361.40	378.16	439.36	470.05	490.34	200.22	
No Fish (million)	99	653	123	114	228	235	178	64	11	8	3	2	1718	
%	5.74	37.99	7.16	6.66	13.25	13.70	10.35	3.72	0.65	0.48	0.18	0.13		
M. length	24.49	26.47	28.61	34.17	35.28	36.24	36.69	37.57	38.11	39.96	40.82	41.37	31.19	
s.d.	0.81	0.99	3.17	1.32	1.35	1.38	1.50	1.74	2.14	1.38	1.07	0.77	5.06	

Figure 6. Mackerel abundance and biomass by age group, left WIIIc-W, right, VIIIc-E.



Behaviour:

In most of the cases, mackerel occured in schools which seem to rise from the sea bottom, as shown in figure 7.



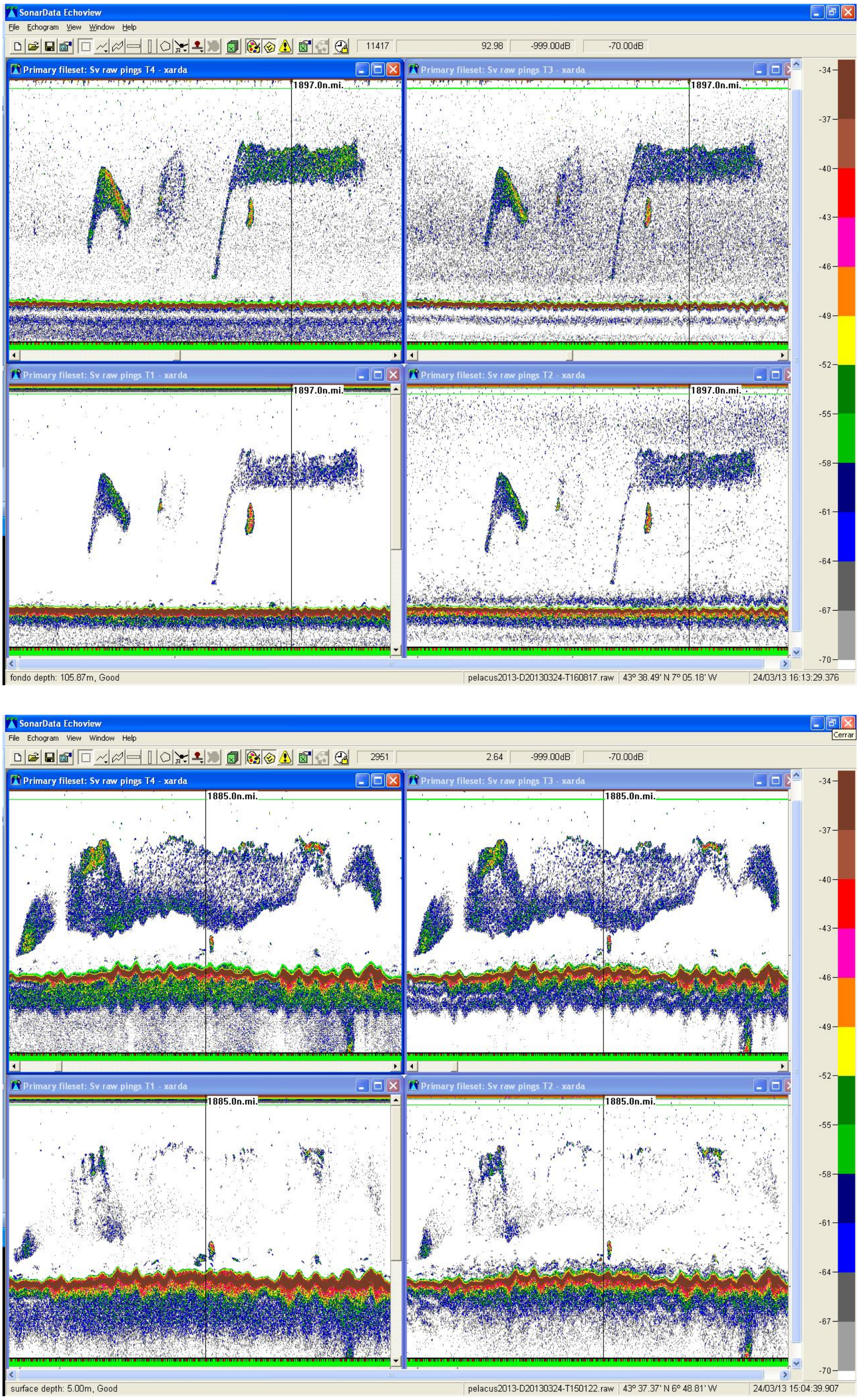


Figure 7. Mackerel occurrence during PELACUS 0313 at 200 kHz (top left), 120 kHz (top right)., 18 kHz (below left) and 38 kHz (below right)

Although an analysis of the schools Sv and NASC values showed an increase in both Sv and NASC at higher frequencies similar to that expected for mackerel, the relative frequency response had different patterns, meaning that in some cases the schools could be not monospecific. Midwater hauls performed on these echotraces, mackerel accounted between 78% and 99,72% of the total abundance, with some bogue and sardine. In situ stomach content analysis of these fish species showed a clear prevalence of mackerel eggs as main diet.

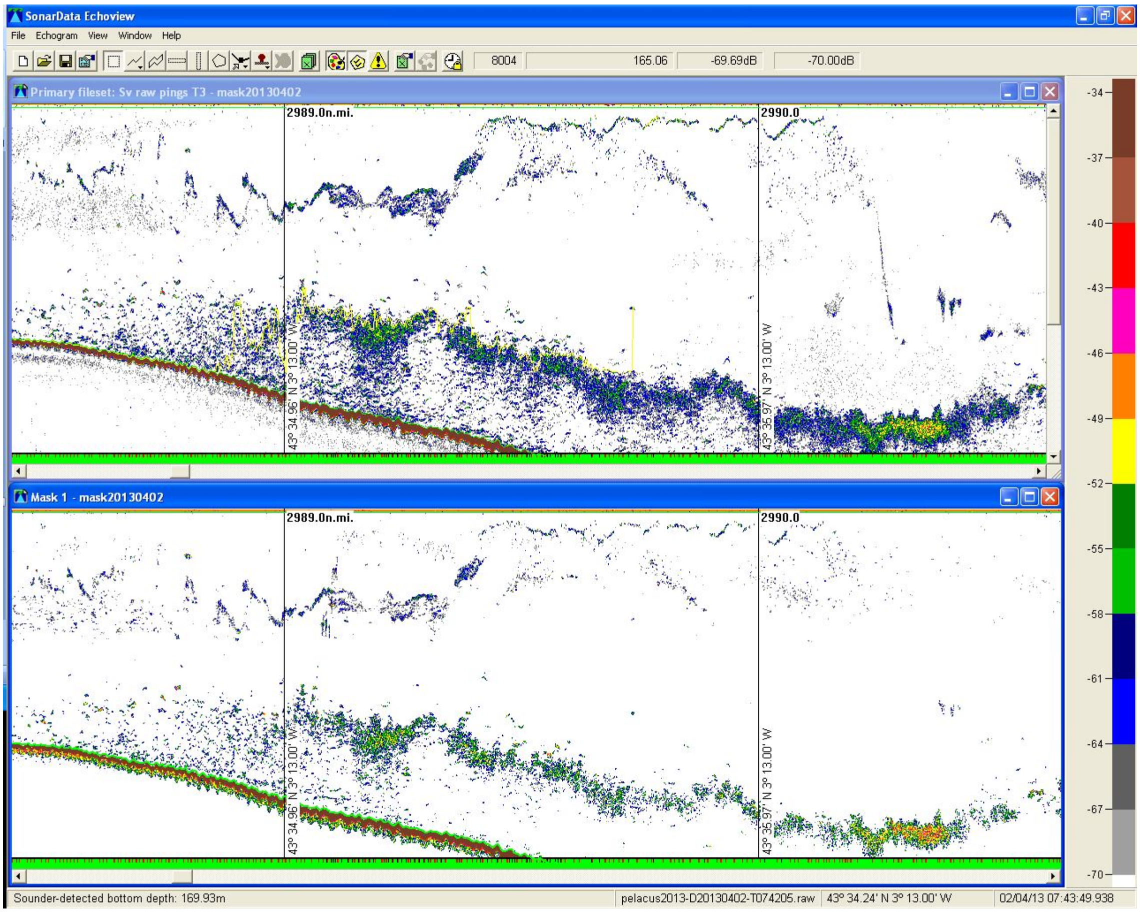


Figure 8. Mackerel occurrence during PELACUS 0313 at 120 kHz (top). and 38 kHz (with mask, below) showing a possible migration to the surface.

Blue whiting distribution and assessment

The extension of the survey track through deeper water allowed the potential blue whiting distribution be covered. In the self-break, a scattering layer around 400-500 m has been found, although the blue whiting abundance inside this was scarce or even nonexistent. We haven't found the typical aggregation pattern in pelagic layer, ribbon-like as often occurs in northern waters, thus being mainly concentrated close to the self break on the continental platform and in the western part of the surveyed area (figure 4). This distribution was higher than that found for mackerel (figure 9)

In 26 fishing stations the total catch in number was higher than 50 individuals, and mean length ranged from 17.4 to 23.5 cm (the later located in Fisterra –NW- and Machichaco –inner part of the Bay of Biscay- capes and in the central part, resulting in 11 post strata on account the differences in both length distributions (significant differences on account K-S test) and mean density, as shown in figure 9.

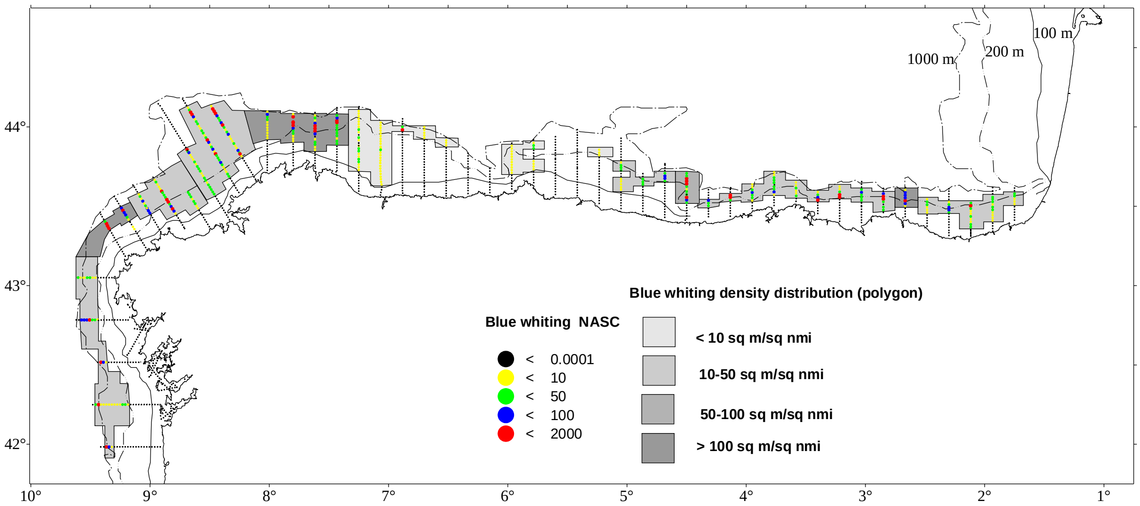


Figure 9. Blue whiting spatial distribution in PELACUS0313 cruise. Polygons are drawn to encompass the observed echoes, and polygon colour indicates the mean integrated energy in m^2 within each polygon (>0-10;10-50; 50-100; and >100 s_A)

Table 7 shows the blue whiting assessment. A total of 13.488 mt has been estimated, corresponding to 299 million fish, which was higher than that assessed the last year (7146 mt corresponding to 123 million fish).

Table 7: Blue whiting acoustic assessment

Zone	Area	No	Mean	Area	Fishing st.	PDF	No (million fish)	Biomass (tonnes)
IXa	Rías Baixas	36	37.72	573	P01-P02	S01	28	1091
	Total	**36**	**37.72**	**573.1**			**28**	**1091**
VIIIc-W	Fisterra	10	122.16	151	P03	S02	15.51	1230.31
	Artabro	34	48.81	361	P04-P05-P06-P07	S03	7.25	318.32
	Capelada	76	47.02	653	P08-P10	S04	42.88	1485.24
	Estaca	49	283.52	442	P13-P14-P16-P17	S05	157.44	6542.00
	Total	***169***	***502***	***1606***			***223***	***9576***
VIIIc-E	Masma	61	6.70	472	P18-P33-P38-P40-P41	S06	3	196
	Peñas	19	4.63	151	P27-P30	S07	1	46
	Cachucho	4	2.06	34	P27-P30	S07	0	5
	Ribadesella	17	18.74	139	P18-P33-P38-P40-P41	S06	2	161
	Llanes	13	71.36	106	P35	S08	8	426
	Cantabria	50	44.75	410	P18-P33-P38-P40-P41	S06	17	1137
	Machichaco	7	106.33	64	P42	S09	5	456
	Euskadi	38	26.86	292	P43-P44-P45	S10	10	394
	Total	***209***	***27.53***	***1667***			***48***	***2821***
Total IXa		***36***	***38***	***573***			***28***	***1091***
Total VIIIc		***378***	***239***	***3273***			***271***	***12397***
Total Spain		***414***	***221.90***	***3846***			***299***	***13488***

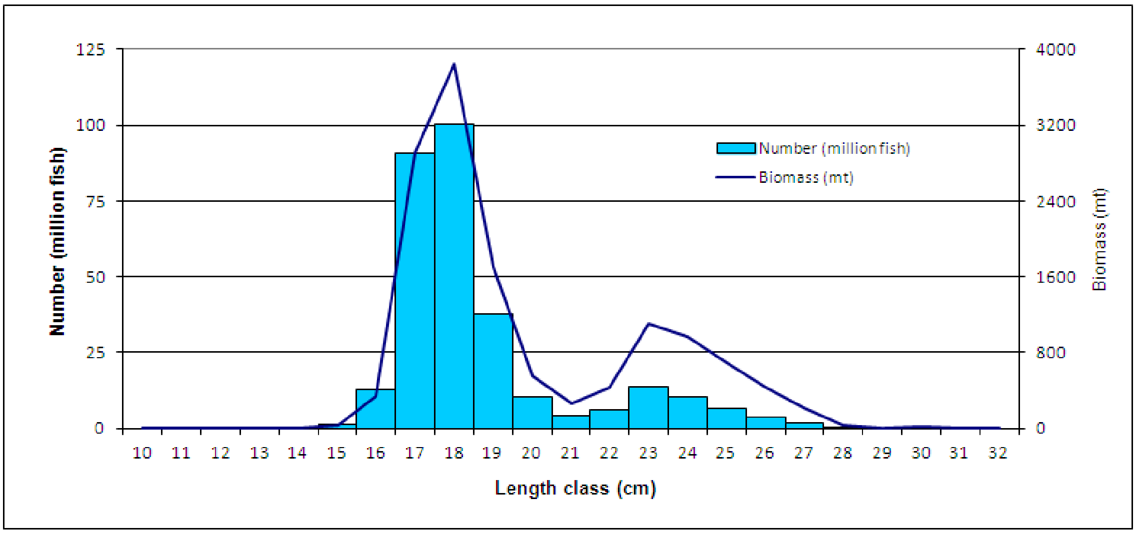


Figure 10. Blue whiting length distribution in both number and biomass during the PELACUS0313 survey.

Horse mackerel distribution and assessment

There is a general declining trend in both biomass estimates and distribution area of horse mackerel. The number of close to bottom schools is scarce as compared to those occurred in the nineties. Besides, only in one fishing station was the most important fish species (57% of the total catch) although it was present in 36 (76%). As observed as well for blue whiting, horse mackerel uses to remain close to the sea bottom, thus less accessible to pelagic fishing gears and probably with a certain degree of underestimation due to the depth zone near the sea floor. In four locations the same mid water haul (i.e. between 5-15 m off bottom) was repeated close to the sea bottom (around 0.5-1 m over the seafloor) giving significant differences in fish species proportion as shown in table 8.

Table 8: Differences in % obtained in fishing hauls performed in the same area at different depths

Area	Haul	% WHB	% MAC	% HOM
Cape Peñas	Pelagic	1.6	96.6	0.0
	Close bottom	77.1	19.0	2.0
Lastres	Pelagic	0.0	73.2	3.1
	Close bottom	0.0	17.2	61.0
Santander	Pelagic	7.8	55.3	29.6
	Close bottom	29.2	6.8	57.5
Santoña	Pelagic	13.6	86.0	0.0
	Close bottom	33.1	59.1	5.9

It should be also noted the heterogeneity in length distribution found along the surveyed area. In the central and western area, a bimodal distribution (peaks in 18-19 cm and 30 cm) was found, although the first peak was clearly smaller than the second. On the contrary, in the inner part of the Bay of Biscay, most of the individuals were smaller than 26 cm, with secondary small peaks at around 20-24 and 30 cm. Close to Cape Ortegal, and related with the main bluejack mackerel distribution, a pure juvenile area (17 cm mode) has been found. Complementary, close to Llanes and mainly outside the self-break, no mode at 17 cm nor at 30 cm has found, with de bulk of the distribution ranged between 18-32 cm Accordingly, the distribution area was divided in 9 post strata, as shown in figure 11.

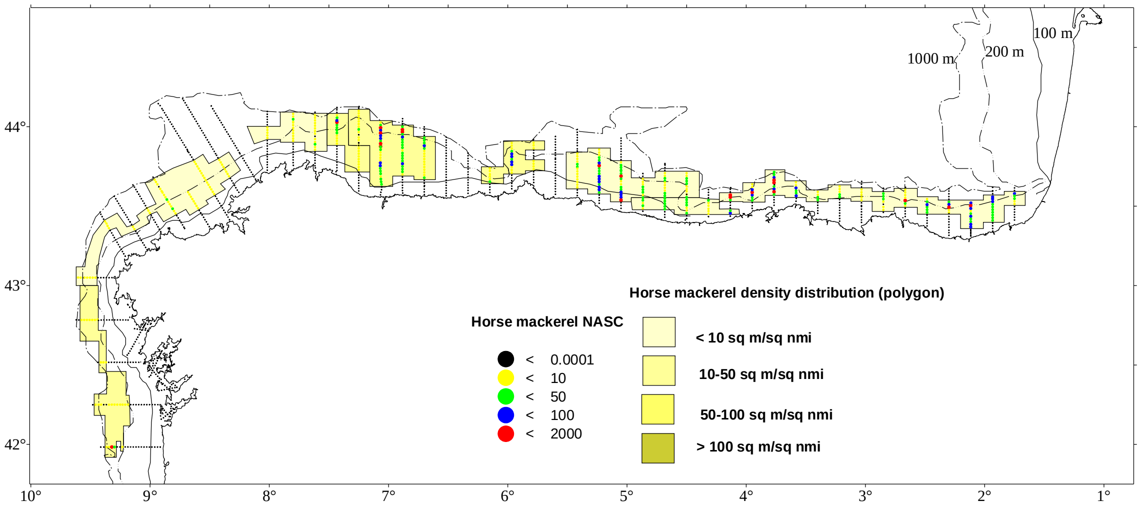


Figure 11. Horse mackerel spatial distribution in PELACUS0313 cruise. Polygons are drawn to encompass the observed echoes, and polygon colour indicates the mean integrated energy in m^2/nm^2 within each polygon (>0-10;10-50; 50-100; and >100 s_A)

Table 9 shows the horse mackerel assessment. A total of 6.372 mt has been estimated, corresponding to 44million fish, which was smaller than that assessed the last year (18264 mt corresponding to 110 million fish).

Table 9: Horse mackerel acoustic assessment

Zone	Area	No	Mean	Area	Fishing st.	PDF	No (million fish)	Biomass (tonnes)
IXa	Rías Baixas	22	13.69	460.05	P20-P30-P31-P33-P35	S03	4	840
	Total	**22**	**13.69**	**460.05**			**4**	**840**
VIIIc-W	Artabro	64	0.59	688	P20-P30-P31-P33-P35	S03	0.29	54.40
	Estaca	31	1.61	280	P17-P18-P22	S01	0.83	37.48
	Total	***95***	***2***	***968***			***1***	***92***
VIIIc-E	Masma	23	19.66	186	P20-P30-P31-P33-P35	S03	3	487
	Asturias Occ	76	42.75	590	P20-P30-P31-P33-P35	S03	18	3366
	Peñas	25	12.89	209	P20-P30-P31-P33-P35	S03	2	359
	Asturias or	79	1.80	593	P20-P30-P31-P33-P35	S03	1	142
	Llanes	24	44.77	187	P34-P36	S04	14	841
	East. Cant	91	2.73	745	P21-P32-P35-P37-P38-P40-P44-P45	S02	2	244
	Total	***318***	***17.26***	***2510***			***39***	***5440***
Total IXa		***22***	***13.69***	***460.05***			***4***	***840***
Total VIIIc		***413***	***14***	***3478***			***40***	***5532***
Total Spain		***435***	***13.79***	***3938***			***44***	***6372***

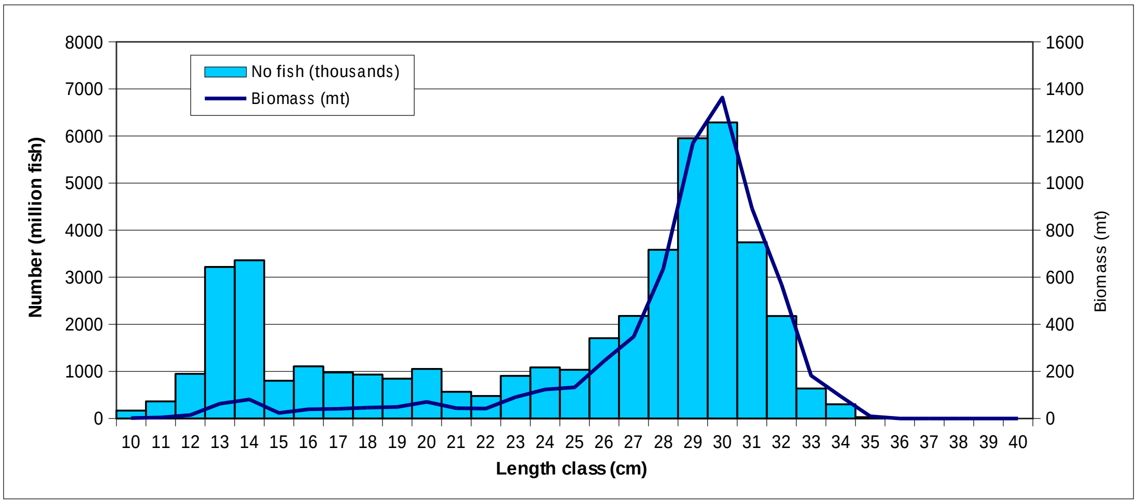


Figure 12. Horse mackerel length distribution in both number and biomass during the PELACUS0313 survey.

Table 10. Horse mackerel abundance in number (thousand fish) and biomass (tons) by age group and ICES sub-area in PELACUS0313.

					AGE GROUPS											
Length	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Total	No fish (thou
10	2															1.55	168
11	4															4.39	363
12	15															14.68	947
13	63															62.62	3217
14	81															80.76	3359
15	23															23.47	801
16	39															39.05	1108
17	41															40.95	977
18	46															46.04	932
19	49															48.83	846
20	55	15														70.43	1052
21	31	13														43.68	567
22	3	16	23													42.09	477
23		34	42	15												90.69	904
24			66	53	4											123.08	1085
25				95	33	4										132.11	1035
26				20	183	41										244.04	1706
27					252	96										347.69	2178
28					149	392	95									635.87	3584
29					19	622	434	38	19	38				19	19	1169.29	5952
30						122	419	542	175		17	87	17		87	1363.30	6288
31								128	398	223	64	80		16	48	892.63	3742
32									142	325	81	20	20	20	41	569.04	2175
33									10	71	81	20	20		30	182.14	636
34											24	71	24		24	94.06	301
35												9	9		9	9.39	28
36																	
37																	
38																	
39																	
40																	
Biomass (t)	451	78	130	183	640	1277	948	707	745	657	267	288	91	55	258	6372	44428
%	7.08	1.23	2.04	2.87	10.05	20.05	14.88	11.10	11.68	10.31	4.19	4.51	1.43	0.87	4.05		
M. weight	29.72	84.60	103.58	121.62	155.95	185.67	202.42	219.06	235.81	250.30	261.75	250.61	272.02	228.04	240.83	118.92	
No Fish (million)	13.98	0.92	1.25	1.50	4.09	6.86	4.68	3.23	3.15	2.62	1.02	1.14	0.33	0.24	1.06	44.43	
%	31.46	2.07	2.82	3.38	9.21	15.44	10.53	7.26	7.09	5.89	2.29	2.56	0.75	0.54	2.39		
M. length	15.58	22.19	23.76	25.08	27.28	28.94	29.80	30.61	31.38	32.02	32.50	32.03	32.93	31.02	31.60	24.89	
s.d.	2.65	1.21	0.78	0.80	0.95	0.94	0.66	0.46	0.76	0.94	1.07	1.60	1.63	1.30	1.53	6.84	

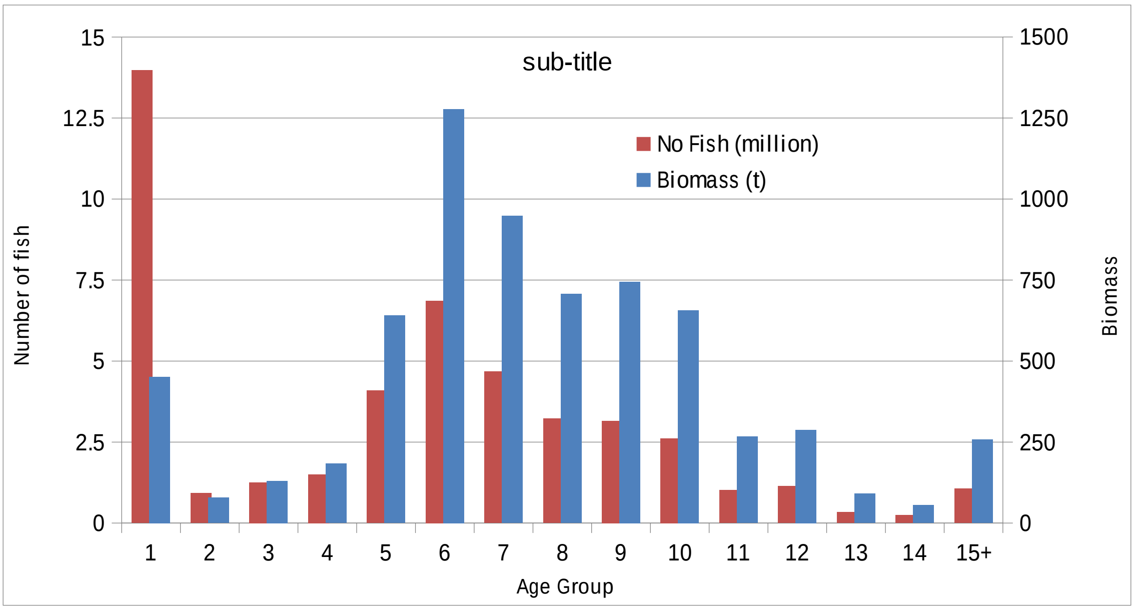


Figure 13. Horse mackerel abundance and biomass by age group.

Bluejack mackerel distribution and assessment

Normally, together with the *T. trachurus*, mediterranean horse mackerel (*T. mediterraneus*) used to be assessed. However, this year, due to the problems for fishing in coastal areas, an important amount of echotraces, most of them in the main mediterranean horse mackerel distribution, where left as unallocated, thus below the assessment acoustic threshold. Complementary, bluejack mackerel has been found in some of the hauls done close to the self-break, especially in the Galician part of the Cantabrian sea (NW).

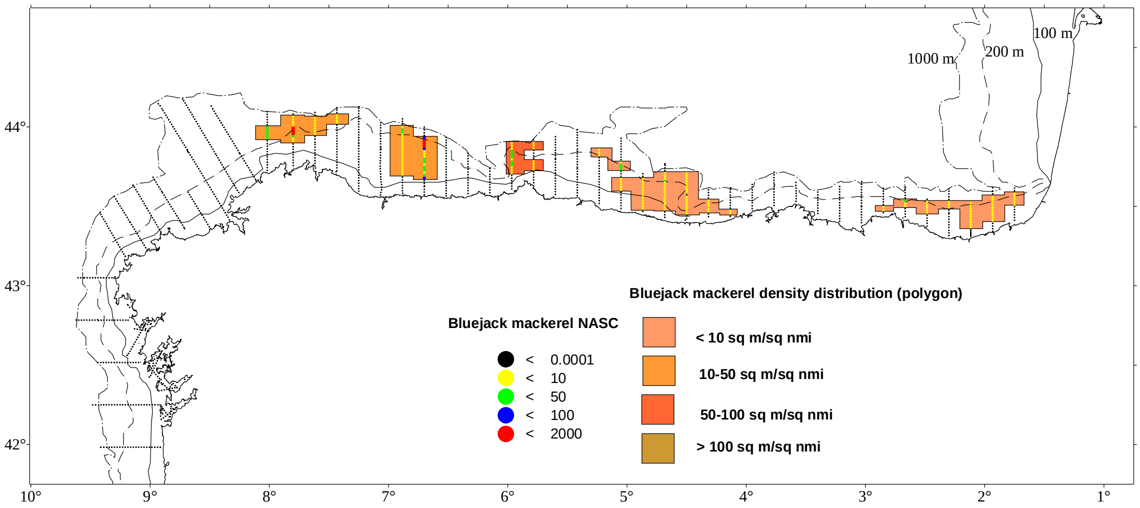


Figure 14. Bluejack mackerel spatial distribution in PELACUS0313 cruise. Polygons are drawn to encompass the observed echoes, and polygon colour indicates the mean integrated energy in m^2/nm^2 within each polygon (>0-10;10-50; 50-100; and >100 s_A)

In spite the length distribution were almost similar, ranging between 13 to 24 cm, and only one fishing station gave significant differences in length distribution, 6 post-strata were needed due to the patchy distribution found in the surveyed area.

Table 11 shows the bluejack mackerel assessment. A total of 1.613 mt has been estimated, corresponding to 31million fish.

Table 11: Bluejack mackerel acoustic assessment

Zone	Area	No	Mean	Area	Fishing st.	PDF	No (million fish)	Biomass (tonnes)
VIIIc-W	Ortegal	27	41.76	227	P14-P22-P34	S01	15	800
	Total	***27***	***42***	***227***			***15***	***800***
VIIIc-E	Caridad	35	27.11	302	P14-P22-P34	S01	13	689
	Peñas	20	4.28	135	P14-P22-P34	S01	1	49
	Asturias Or	56	0.59	445	P14-P22-P34	S01	0	22
	Cachucho	6	6.52	58	P30	S02	1	30
	Euskadi	56	0.59	445	P14-P22-P34	S01	0	22
	Total	***173***	***6.59***	***1385***			***15***	***813***
Total VIIIc		***200***	***11***	***1612***			***31***	***1613***
Total Spain		***200***	***11***	***1612***			***31***	***1613***

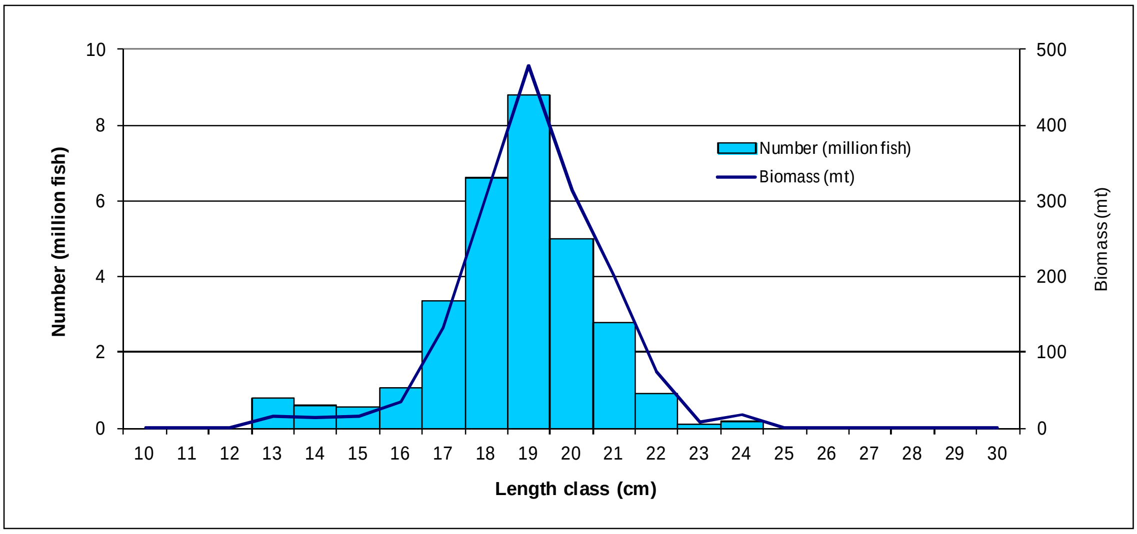


Figure 15. Bluejack mackerel length distribution in both number and biomass during the PELACUS0313 survey.

Board fish distribution and assessment

This year only few board fish were detected, most of them directly assigned accounting its particular school morphometric and backscattering properties.

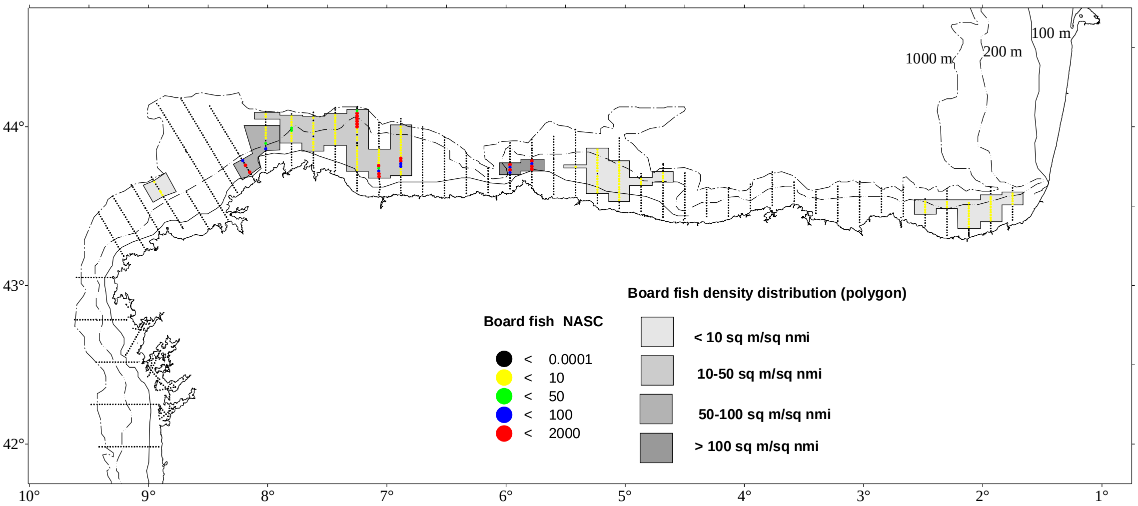


Figure 16. Board fish spatial distribution in PELACUS0313 cruise. Polygons are drawn to encompass the observed echoes, and polygon colour indicates the mean integrated energy in m^2/nm^2 within each polygon (>0-10;10-50; 50-100; and >100 s_A)

A total of 16067 tonnes were estimated, corresponding to 437 million fish (table 12), which represents a drastic decrease since 2011 when more than 220 thousand tonnes were estimated. Last year the total biomass assessed were 33.238 corresponding to 518 million fish.

Table 12: Board fish acoustic assessment

Zone	Area	No	Mean	Area	Fishing st.	PDF	No (million fish)	Biomass (tonnes)
VIIIc-W	Artabro	7	0.00	69	P14	S01	0.0	0.07
	Capelada	15	56.16	171	P14	S01	164.58	2615.15
	Total	***22***	***36***	***240***			***165***	***2615***
VIIIc-Ew	Masma	94	37.17	736	P19	S02	214	10315
	Peñas	9	111.40	73	P28	S03	58	3132
	Asturias Or	42	.03	328	P28	S03	0	4
VIIIc-Ee	Euskadi	33	0.01	280	P28	S03	0	1
	Total	***178***	***76***	***1416***			***273***	***13452***
Total VIIIc		***200***	***71.45***	***1675***			***437***	***16067***
Total Spain		***200***	***71.45***	***1675***			***437***	***16067***

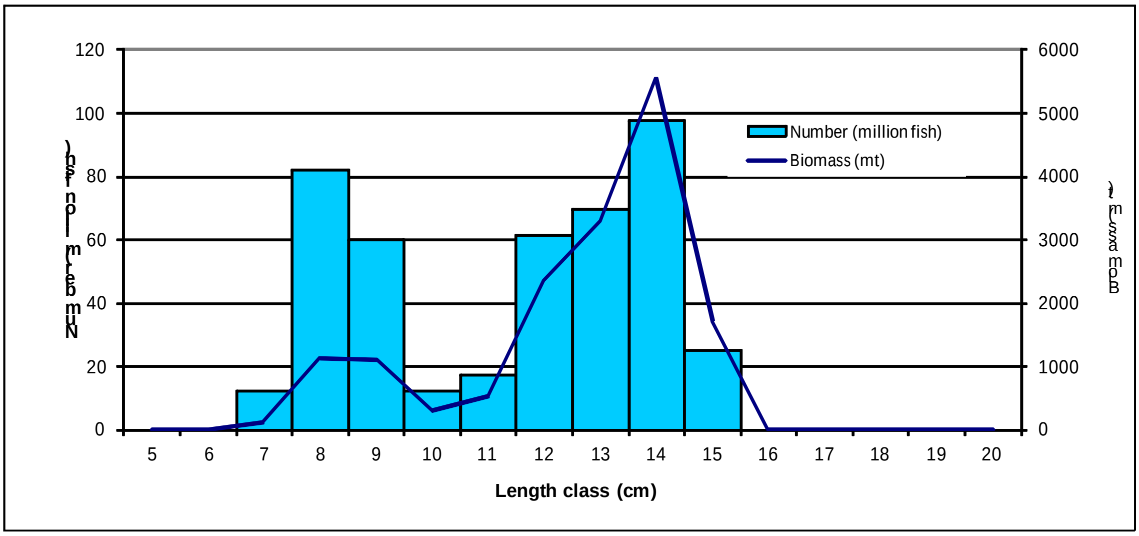


Figure 17. Board fish length distribution in both number and biomass during the PELACUS0313 survey.

The main difference between this year assessment and the previous one is the presence os a second mode at 8 cm, which explains the lower difference in number (from 437 to 518 millions fish found last year) as compared with that found in biomass (from 16 thousand tonnes to 32 thousand tonnes).

Other fish species

Only bogue (Boops boops) has an important contribution to the pelagic community; on the contrary, sardine, anchovy or mediterranean horse mackerel had a lesser contribution, with only few tonnes.

Discussion

PELACUS 0313 was characterised by both the bad weather conditions and the change of the R/V Thalassa by the R/V Miguel Oliver. In spite, no intercalibration between these ships has been made. This exercise would be done next year. Vessel effect on acoustic assessment is very difficult to achieve when both vessels have similar characteristics (i.e. low noise radiated level). We believe the vessel effect on the total NASC recorded would be negligible since no differences in fish behaviour should be expected due to the similar vessel characteristics. Another source of random error is the fishing stations which could change the species composition and/or proportion of the pelagic community. Again, the pelagic trawl with a vertical opening of about 16-18 m (20-25 in horizontal one) would have had the same performance as the Thalassa one. We had not seen any particular escaping behaviour in front of the gear and we assumed the fishing stations were ground-truthing. Unfortunately, schools close to the coast were inaccessible to the fishing gear, nor it was possible to allocate directly into fish species on account their morphological, acoustic and geographical characteristics.

On account this last feature, we were only able to properly assess the off-shore pelagic community, resulting, therefore, a very low biomass estimation for more coastal species such as sardine with only 3343 metric tonnes.

Nevertheless, an important amount of schools were detected close to the coast, in shallower waters in a very hard and rough sea bed, thus no accessible to the pelagic year, and these represented 33% of the total backscattering energy. Between 1992 and 2002, in coastal waters (depth <90m) sardine achieved up to 67% of the total backscattering energy (12% in deeper waters than 90 m), ranging from 40% up to 75%. If we assume that such proportion of backscattering energy for sardine in coastal waters is stable and independent of the total energy and also assuming that the sardine eggs collected in the CUFES is a good estimator of the sardine spawning biomass distribution, then the biomass estimation including an estimated proportion ranging between 30% to 60 % of the unallocated backscattering energy in coastal waters will increase the estimation in around 7 to 13 thousand tonnes (10-16 thousand tonnes in total), which is still too low.

In spite the lack of fishing stations in coastal waters allowing distributing the backscattering energy into fish species, we can conclude that the sardine biomass would remain in the lowest level of the time series, with no signal of recovery, nor of a good incoming year class in the surveyed area (IXa-North and VIIIc). In the same way, horse mackerel and board fish seems to decrease both in abundance and distribution area. Mackerel, as in the previous years, was the most abundant fish species. The bulk of the juvenile (60 % were inmature) was found in the NW area (i.e. north Galician waters) whilst the adult stock was mainly concentrated in the eastern part. In this area we did two extra egg oblique-tows from sea surface to 50 m depth, controlled by a scanmar sensor put in the wire and monitored through the EK-60.

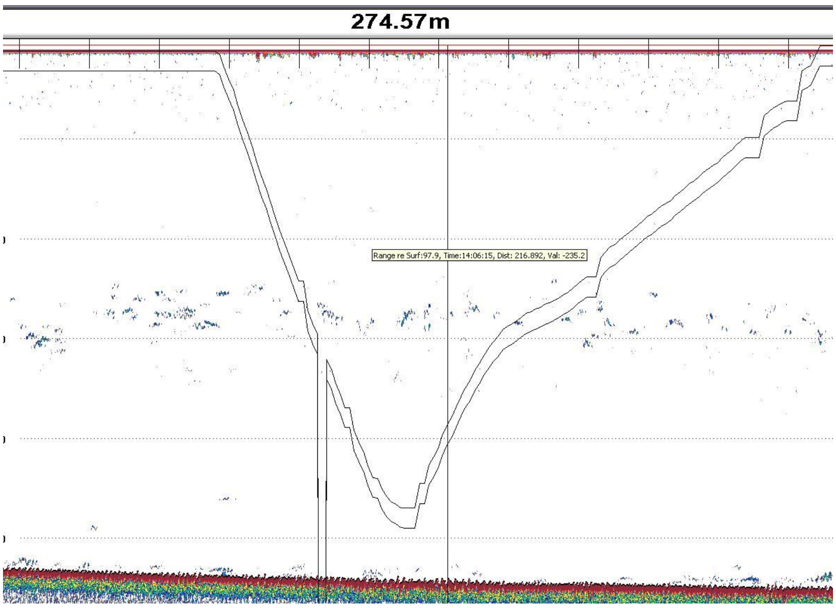


Figure 18.Example of monitoring an oblique plankton tow, through a scanmar depth sensor integrated in the EK-60.

In a specific tow, after 15 minutes we collected more than 1000 mackerel eggs together with 21 larvae. It seems that mackerel undertakes vertical migration to upper layers, but, yet, we could not establish a deterministic pattern for this behaviour. Whether there is a specific timing and purpose for this movement should be studied in future surveys. Together with these plankton tows, we have also analysed the bogue and sardine stomach contents. As expected, most of the preys were mackerel eggs. Contrary to the expected normal behaviour, these fish species (and also sometimes horse mackerel) did not occur in shoals or schools, as they seem to be aggregated in small spots, almost dispersed, similar to the night behaviour, as shown in figure 19

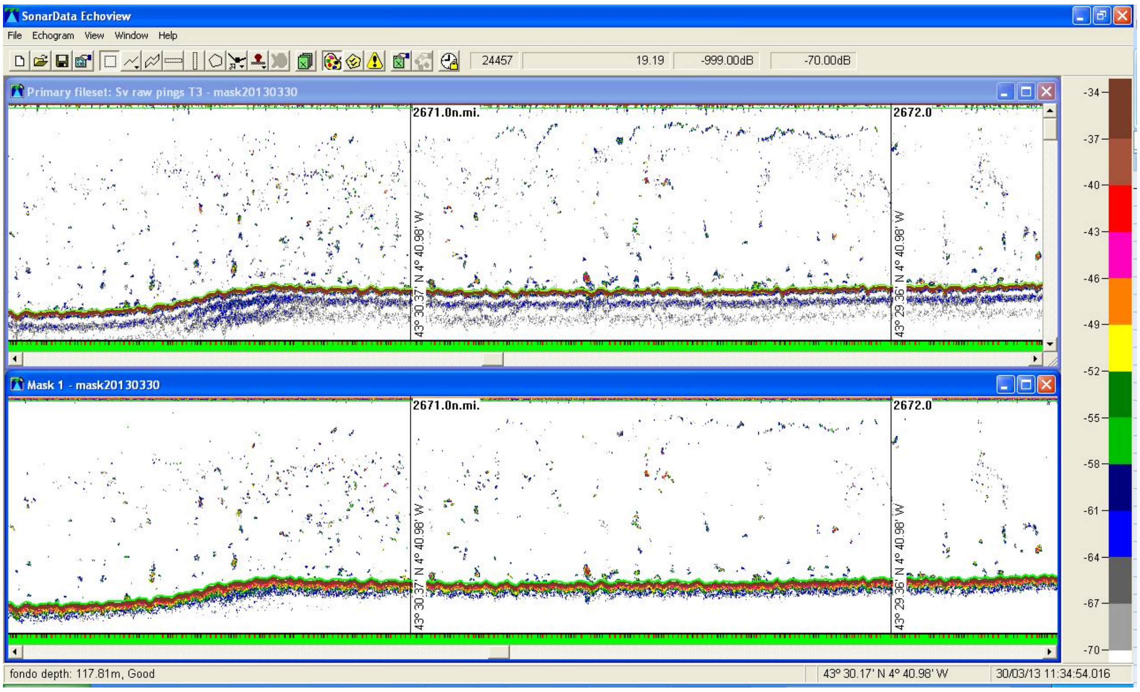


Figure 19. Dispersed aggregation pattern occurred during day time

As PELACUS is a multidisciplinary survey series (we collect environmental and biological ancillary information, stomach contents, including CTD cats, plankton tows or continuous records of plankton, eggs, S, T and flourometry), we will try to explain this change of behaviour. Our main hypothesis is that these species could follow mackerel when is undetaking vertical migration, probably related with the spawning activity, just for feeding eggs and, therefore, changing the expected schooling behaviour by the dispersed one, used during the feeding activity.

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We would like to thank all the participants and crew of the PELACUS surveys.

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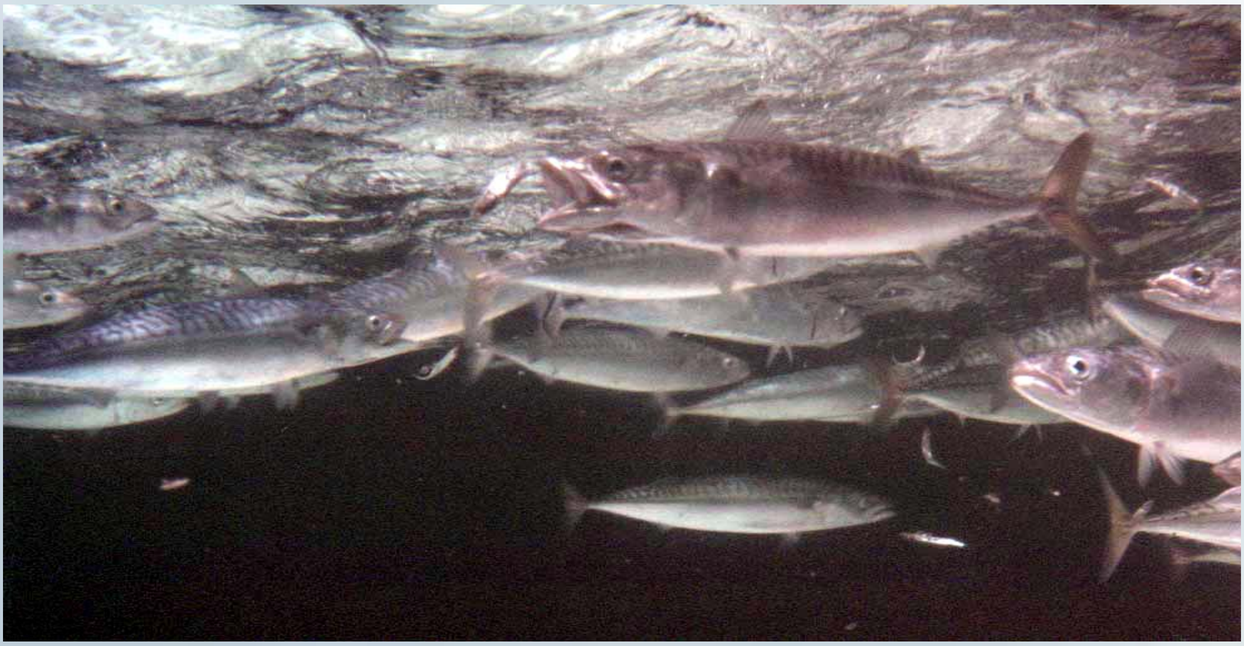
SCHOOLING DYNAMICS OF SUMMERTIME MIGRATING NORTHEAST ATLANTIC MACKEREL (*SCOMBER SCOMBRUS*) IN THE NORWEGIAN SEA USING MULTIBEAM SONAR



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June 2013

Feeding mackerel school at the surface. Photo: T.G. McInnes, British Marine Life Study Society
M/V “Brennholm”. Photo: Justine Diaz

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Bergen, June 2013

Justine E. Diaz

Abstract

Pelagic fish in the Norwegian Sea perform seasonal migrations from overwintering, via spawning, to feeding grounds. Northeast Atlantic (NEA) mackerel (*Scomber scombrus*) are highly migratory, fast-swimming, and an obligate schooling fish. The schooling dynamics of NEA mackerel in nature is largely unknown because they lack a swimbladder, resulting in a weak acoustic signature, and therefore are difficult to detect in the summer when swimming in loose school formations. However, high frequency omnidirectional SONAR (SOund Navigation And Ranging) is capable of detecting NEA mackerel in the acoustic echosounder blind zone close to the surface. Acoustic, biological, and temperature data were used to study the schooling dynamics of NEA mackerel in relation to temperature, zooplankton abundance and density of conspecifics in four geographically separate regions of the Norwegian Sea during summer. These results show that there were regional differences in fish size, swimming speed and direction, school depth, temperature and zooplankton abundance. The thermocline depth had a profound influence on the depth distribution of schools throughout the Norwegian Sea during summer. NEA mackerel were consistently found shallower than 40 m depth where the temperature was at least 6° C. The fish generally swam north except for in the SW region, coinciding well with prevailing current directions. Fish were significantly larger in the north than in the south, and plankton abundance was higher in the west than in the east. The observed school dynamics in relation to abiotic and biotic factors are explained in terms of the ecology of NEA mackerel during the summer feeding migration.

Keywords: schooling, NEA mackerel, Norwegian Sea, feeding, behaviour, multibeam SONAR

Contents

Introduction

Background

The Norwegian Sea is a large feeding ground and migration highway for highly abundant stocks of pelagic fish during their feeding migration in the late spring and summer months (Skjoldal *et al.* 2004; Huse *et al.* 2012; Utne *et al.* 2012). Major commercial species in this area are NEA mackerel (*Scomber scombrus* L.), Norwegian spring-spawning (NSS) herring (*Clupea harengus* L.) and blue whiting (*Micromesistius poutassou*) (Iversen *et al.* 2004; Holst *et al.* 2004; Monstad 2004). Long distance migrations and extensive distributions are key features of these and other pelagic planktivorous fish species (Nøttestad *et al.* 1999; Skjoldal *et al.* 2004). Pelagic fish stocks can be exceptionally abundant, consisting of several million tonnes and billions of individuals, and may have a great impact on the ecosystem by depleting large amounts of zooplankton (e.g. Ayón *et al.* 2008; Huse *et al.* 2012; Langøy *et al.* 2012; Utne *et al.* 2012). Migrating species, such as NEA mackerel, are important components in the food web; as major predators and prey (Iversen 2002; 2004) and competitors with other pelagic fish species (Prokopchuk and Sentyabov 2006; Huse *et al.* 2012; Langøy *et al.* 2012). They also contribute to shifting nutrients across great distances from open oceans to coastal waters (Dragesund *et al.* 1997; Varpe *et al.* 2005). The NEA mackerel stock in 2010 was estimated to be 4.5 million tonnes from trawl catches and swept area calculations north of 62° N (Nøttestad *et al.* 2010). The official spawning stock biomass according to ICES was 2.9 million tonnes (ICES 2012). Presently, neither hydro-acoustic methods with SONAR and echosounder nor the swept area methodology based on standardized pelagic trawling are properly evaluated and accepted as quantitative input series to the ICES mackerel assessment. Nevertheless, the results indicate a strong and robust mackerel population steadily increasing in the Norwegian Sea in summer (Nøttestad *et al.* 2013). This is partly a result of record high recruitment from the 2002, 2005 and 2006 year classes, coinciding with record high sub-surface temperatures (Nøttestad *et al.* 2013). However, zooplankton concentrations are steadily declining in the Norwegian Sea (Huse *et al.* 2012; ICES 2012; Utne *et al.* 2012).

Biology of NEA mackerel

Many pelagic fish species migrate annually from overwintering, via spawning, to feeding areas during their lifetime (Harden Jones 1968; Arnold and Cook 1984; Dingle 1996). NEA mackerel is a fast swimming pelagic fish with high endurance that is highly migratory, performing summer feeding migrations northwards from the spawning grounds around 40 -

60° N to 72° N via the Norwegian Sea, but has also been recorded north to 73° N (Holst and Iversen 1992; Iversen 2004) and even up to 75° N (Nøttestad *et al.* 2010). The distribution and abundance of NEA mackerel in this area has presumably varied considerably over the years and during the last decades depending on sea temperature and feeding conditions (Iversen 2004; Utne *et al.* 2012). Iversen (2004) stated that NEA mackerel prefer sea temperatures of 8° C or warmer; however, on the western side of the North Atlantic, mackerel were found to prefer to waters of at least 7° C along the east coast of North America (Castonguay *et al.* 1992). They have even been recorded down to 0° C in the Gulf of Saint Lawrence (Castonguay *et al.* 1992). NEA mackerel mainly occur in the upper 40 m of the water column during summer (Godø *et al.* 2004) and rely on light when selectively feeding on the later copepodite stages (IV-VI) of Calanoid copepods, in particular, *Calanus finmarchicus* (Iversen 2004; Prokopchuk and Sentyabov 2006; Langøy *et al.* 2012). Higher latitudes provide extended daylight hours and higher production of phyto- and zooplankton in spring and summer, and therefore, longer available feeding period for these visual feeders (Nøttestad *et al.* 1999). However, NEA mackerel are known to hunt their prey by active particulate feeding and passively filter feeding while swimming with their mouths wide open. Passive filter feeding contributes to effective plankton feeding when in less aggregated prey concentrations, and at the same time enables fish to pass more water over the gills for improved oxygen uptake needed for rapid, constant swimming (Macy *et al.* 1998; Iversen 2004).

Currents in the Norwegian Sea

The Norwegian Sea is bound by the warmer northerly Atlantic and coastal currents to the east and by the cooler southerly Arctic front to the west (Figure 1). Oceanic currents transport zooplankton, but also enforce temperature barriers. The Atlantic and coastal currents drive warm southern water up along the Norwegian coast, while the Arctic front distributes the cold Arctic water towards the surface in the western Norwegian Sea. The Gulf Stream brings warm water up the coast of Norway and cold Arctic water is brought south at the western border of the Norwegian Sea (Blindheim 2004; Skjoldal et al. 2004; Figure 1).

Energetic costs of migration can be offset by swimming with the tidal currents (Nøttestad *et al.* 1999, Godø *et al.* 2004) or taking advantage of gyres and eddies in the Norwegian Sea and along the Norwegian coast (Godø *et al.* 2012). Castonguay and Beaulieu (1993) found that mackerel utilized the tidal streams at flood tide and high tide to reach their spawning grounds off the northeast coast of North America, and refer to this behaviour as “selective tidal stream transport” (STST). Larval organisms passively utilize the tidal streams for transportation (Castonguay and Gilbert 1995), but whether this continues into adulthood for the summer feeding migration is unknown.

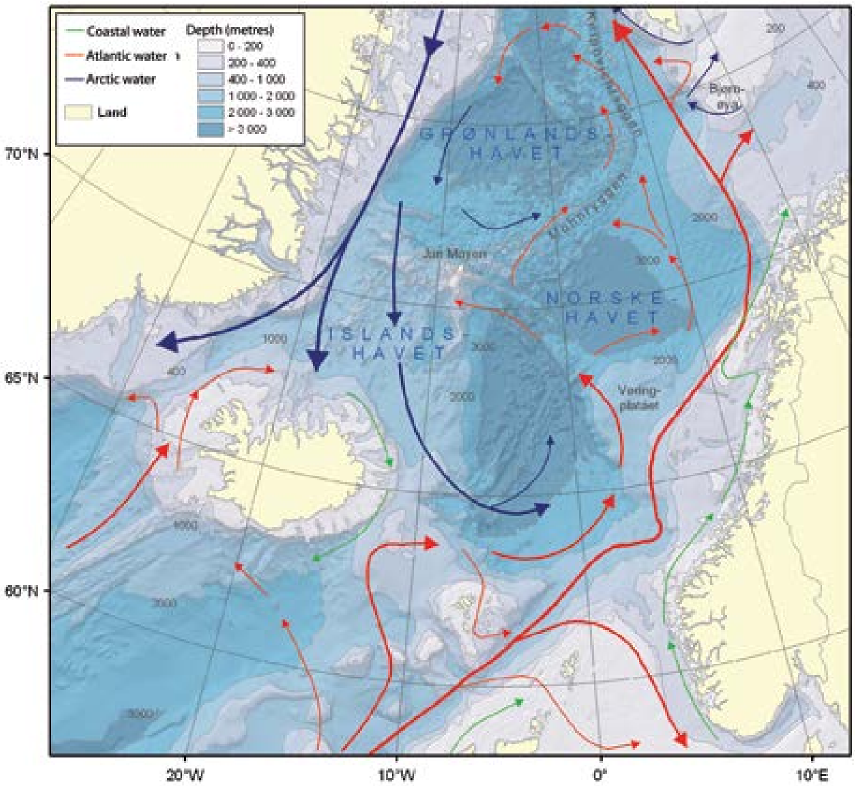


Figure 1. Coastal and oceanic water masses flowing through the Norwegian Sea and surrounding waters (Institute of Marine Research/Norwegian Coastal Administration).

Advantages of schooling

Schooling is common in pelagic fishes, and mackerel are a known obligate schooler (van Olst and Hunter 1970; Parrish *et al.* 2002). Numerous studies have been conducted on the schooling dynamics of NSS herring with regards to their macro- and meso-scale distributions (horizontal and vertical), school size, swimming speed and direction, feeding behaviour and diurnal behaviour (e.g. Misund 1993; Mackinson *et al.* 1999). These studies provide baselines for comparisons with mackerel, considering that they are also a pelagic migrating species, and thus probably exhibit similar schooling dynamics. The advantages of schooling for small planktivores include: improved hydrodynamics, enhanced food finding and protection from predators (Pitcher and Parrish 1993; Parrish and Edelstein-Keshet 1999; Krause and Ruxton 2002). Individual fish within a school modify their behaviour on a second to second basis based on individual needs, and observed behaviours are collected and linked from meters to kilometres (Mackinson *et al.* 1999; Nøttestad *et al.* 2004). Adaptive responses to the environment contribute to the short-term gain for the individual and the long-term function of the group (Parrish *et al.* 2002). The "optimal school size" concept aims for a maximised net benefit through a balance of costs and benefits (Pitcher and Parrish 1993; Krause and Ruxton 2002). Unfortunately, the "optimal school size" is naturally unstable and determined by the balance of trade-offs to individuals within the group, where size of the group affects its performance (Clark and Mangel 1986; Parrish and Edelstein-Keshet 1999; Hoare *et al.* 2000). The spatial organization of schools also varies between spawning and feeding migrations (Nøttestad *et al.* 1996, Fernö *et al.* 1998; Nøttestad *et al.* 2007). When feeding tendency is strong and predation risk is low, schools are likely to split up and become loosely aggregated (Pitcher and Parrish 1993).

NEA mackerel are a long-lived species with a lifespan of more than 20 years (Iversen 2004), suggesting that mackerel prioritize potentially threatening situations over feeding when neccessary, as has been discussed for herring (Fernö *et al.* 1998). Individual NEA mackerel, and NSS herring, form large, dense schools to reduce their individual predation risk from whales and other predators through a dilution effect (Misund 1993; Vabø and Nøttestad 1997; Nøttestad *et al.* 2002; 2004). Diel vertical migration (DVM) from deep waters during day time to shallow water at night is a widespread behavioural strategy in the pelagic habitat (Huse and Korneliussen 2000; Holst *et al.* 2004). DVM is common in pelagic fishes to provide protection from predators by hiding in the deeper waters during the day (Nøttestad *et al.* 2002), but it is also a mechanism of following prey that also performs regular DVM.

Sampling methods

Presently, little information exists regarding the behaviour of NEA mackerel because they are difficult to detect with acoustic equipment when in small, loose schools near the surface of the water because they have no swimbladder (Tenningen *et al.* 2003; Simmonds and MacLennan 2005). Thus, the low acoustic back-scattering from lack of a swimbladder complicates proper quantification of abundances of mackerel from echosounder technology (Korneliussen and Ona 2004; Korneliussen 2010). Omnidirectional SONAR has been used successfully in the past to record migratory behaviour of schooling fish (Godø et al. 2004; Nøttestad *et al.* 1996; 2004; Brehmer *et al.* 2006; Nøttestad et al. 2007). Small schools close to the surface are located in the echosounder acoustic blind zone (a region where fish are above the sampling range of the acoustic beam). High-frequency, long range omnidirectional SONAR have better resolution and mackerel school detection because the transducer is smaller than a low-frequency transducer (Simrad), thereby facilitating studies of mackerel behaviours (Totland *et al.* 2009).

Aims and objectives

The main objective of this thesis was to analyse the distribution, depth, swimming speed and direction, school size and clustering of NEA mackerel schools from July to August 2010 using an omnidirectional multibeam SONAR. These parameters were correlated with physical and biological data to examine their influence on schooling NEA mackerel during the summer feeding migration. It was predicted that while selectively feeding on copepod zooplankton NEA mackerel would form many small, loose aggregations evenly distributed in the upper parts of the water column. Physical (temperature, currents) and biological (prey, potential predators) differences between northern and southern and oceanic and coastal regions were also expected, hence, four geographically separate regions of the Norwegian Sea were selected for inter and intra-regional analyses. The results from this thesis can add to the understanding of behaviour, migration and schooling dynamics of NEA mackerel, as well as, contribute to the new swept area methodology for abundance estimation of NEA mackerel with standardized trawling, which uses the area of the trawl and the collected sample biomass to estimate pelagic fish abundances.

Materials & Methods

Study area

Biological, oceanographic and acoustic data were collected from an ecosystem survey in the Norwegian Sea in July - August 2010. The combined purse seining and pelagic trawling vessels M/V "Brennholm" and M/V "Libas" were employed; however, only data from M/V "Brennholm" were used in this study. Four geographically separate regions from the predetermined cruise tracks in the Norwegian Sea and surrounding waters were the focus for quantitative analysis for this thesis; northwest (NW), northeast (NE), southwest (SW) and southeast (SE) respectively (Figure 2, Nøttestad *et al.* 2010). The regions for analysis were chosen based on geographical separation in terms of latitude and longitude, SONAR data quality and mackerel abundance. Their inherent properties are outlined below (Table 1).

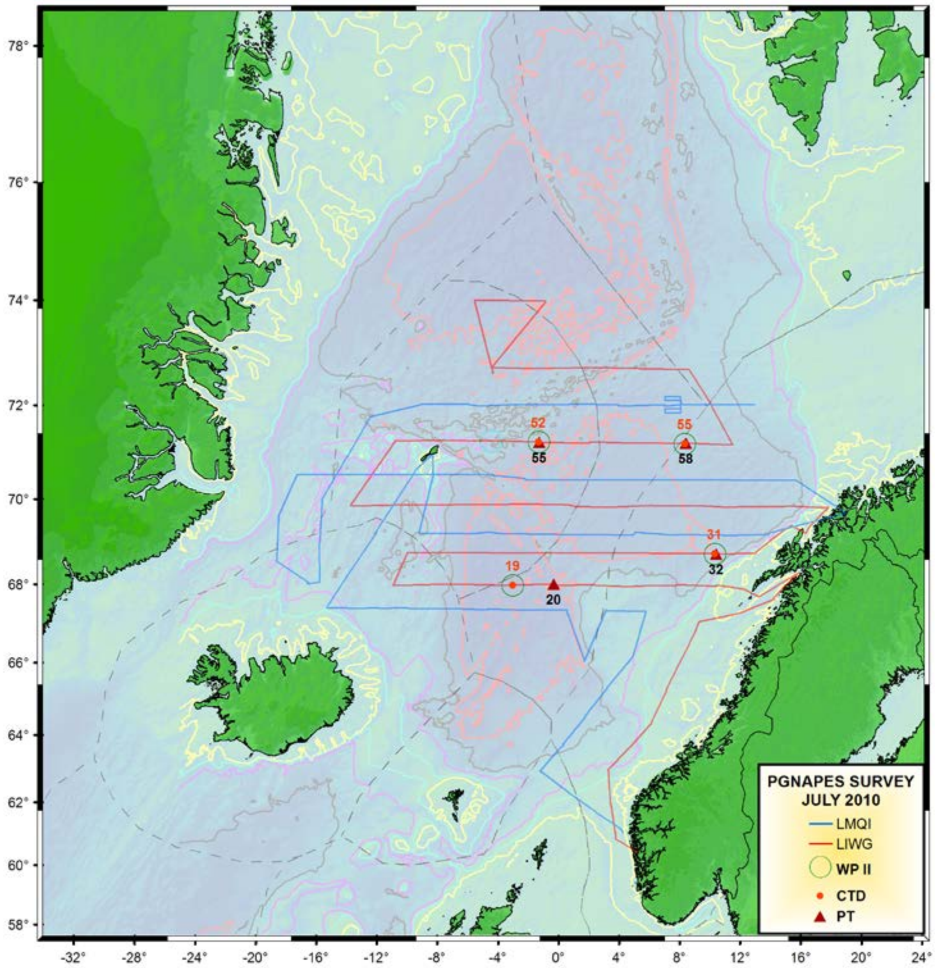


Figure 2. Cruise tracks for M/V "Brennholm" (red line) and M/V "Libas" (blue line) with pelagic trawl (▲), CTD (●) and plankton (○) sampling stations and their corresponding identification number in proximity to the transects used for SONAR scrutinizing.

Table 1. Location (latitude and longitude) of the transects used for acoustic and biological mackerel analysis in the NEA (Norwegian Sea and surrounding waters); including sampling date and bottom depth.

Region	NW	NE	SW	SE
Latitude	71° 15' N	71° 12' N	67° 57' 36" N	68° 43' 12" N
Longitude	2° 3'36" W - 1 15' W	7° 42'00" E – 8° 20'24" E (*day*) 9° 28'48" E - 9° 45'36" E (*night*)	3° 50'16" W - 4° 2'60" W	11° 26'24" E -11° 49'48" E
Date	30 July	31 July - 01 August	20 July	23 July
Bottom depth (m)	>1500 m	>1500 m	>1500 m	>1500 m

Temperature

The temperature data were recorded approximately every 60 nautical miles (nmi) at a predetermined sampling station with a SAIV SD200 (SAIV A/S) Conductivity Temperature and Depth (CTD) sensor. Temperature from the surface to a maximum 500 m depth was recorded every meter in the water column (Nøttestad *et al.*, 2010). Upcast data from 50 m depth to the surface was used for analysis. The depth of the 8° C isotherm was analysed in each region and compared with the mean school depths to evaluate the minimum temperature preference for NEA mackerel.

Acoustic data

Study areas

Four transects were acoustically analysed for NEA mackerel schools in four geographically separate regions; northwest (NW), northeast (NE), southwest (SW), and southeast (SE). These transects (NW, NE, SW, SE) were collected during daylight hours. A night time segment in the NE was located approximately 23 km east of the daytime segment, which was nearly three hours between the last sampled school of the day segment and the first sampled school of the night segment. With the prolonged daylight hours in the summer, a function in the statistical program R version 2.15.1 (R Development Core Team 2012, www.r-project.org) determined the altitude of the sun to discriminate between day and night hours (Appendix 1). The day segment occurred from 19:26-20:23 on 31 July, and the night segment occurred from 23:12 on 31 July to 00:08 on 1 August. The trawl catch from the nearest occurring pelagic trawl station with a proportion of at least 90% mackerel was used to confirm that mackerel was the species detected acoustically.

SONAR data collection and scrutinizing

Acoustic measurements of schooling NEA mackerel and other pelagic fish species, such as NSS herring, were taken continuously throughout the survey using multi-frequency acoustics from the Simrad ER60 echosounder. The echosounder had an opening angle of 8° and operated on five frequencies (18, 38, 70, 120, and 200 kHz). The high frequency Simrad SH80 omnidirectional SONAR has 480 elements and a standard operational frequency of 116 kHz with an 8º horizontal opening angle (9º vertical) (Simrad, www.simrad.no). During the data collection, the SONAR operated from 2-6° tilt angle during collection, and the sampling range was set at 85 to 300 m radius from the vessel.

Large Scale Survey System (LSSS) (www.marec.no) was used for post-processing raw acoustic data (Korneliussen *et al.* 2006). A module in the program, PROFOS, is capable of replaying and filtering raw data, and distinguishing between detected schools and noise (noise: "*unwanted signals that are present in the medium but independent of the echosounder/SONAR transmission,*" Simmonds and MacLennan 2005). The pre-processing function allowed for bypassing the time consuming process of scrutinizing the SONAR manually (Appendix 2).

To minimize any potential vessel avoidance by mackerel schools, only schools within an 85-300 m radius from the vessel were used; the goal being to detect and analyse schools exhibiting natural undisturbed swimming behaviours (Misund *et al.* 1997). Furthermore, detections under the following criteria were excluded from the analysis: consisting of four or less consecutive pings, schools not having a "biologically reasonable" speed (approximately 1 m s^{-1} to 6 m s^{-1}) (see Godø *et al.* 2004) and those appearing as noise (i.e. exhibiting an unnatural swimming pattern, the first detection appearing behind the vessel, and extreme variations in school size).

Mackerel school parameters

After the SONAR data was scrutinized, PROFOS provided means on the following parameters using the ping data per each school: mean depth (m), mean speed (m s^{-1}), mean direction (°), mean backscattering volume (s_v), mean area (m²), geographical school position (longitude and latitude maximum and minimum). The number of pings of the detected school (how many seconds the school was detected) and time and date of the first and last detections were also provided.

School depth was used to analyse the vertical distribution of mackerel. The SONAR provided an estimate of mean school depth ($\overline{m}$) with the range (m) of the detections from the vessel and the opening angle of the transducer (θ) (equation 1).

$$depth(m) = \frac{range(m)}{\tan\theta} \tag{1}$$

To estimate the biomass (kg) of each school, two assumptions were made:

1. The schools were ellipsoid shaped, which reduces drag for migrating schools (Himelrijk *et al.* 2010; Misund 1993; Pitcher 1993).
2. The packing density was one fish per cubic metre in every school, because the SONAR was not calibrated, thus providing an s_v value that was only a relative measure of the acoustic energy from a school (Misund 1990).

To estimate the biomass of mackerel schools in kg, the relative school volume was calculated using the provided area (m²) from the SONAR output. Given that the height (m) (*h*) was equal to the width ($z=h$) and the length was three times the height ($l = 3 \cdot h$), the area (equation 2) was used to determine the dimensions of a theoretical ellipsoid school shape (equation 3), and in turn was used to estimate a relative volume (equation 4). The volume (m³) (*V*) was equal to the number of fish in each school. The number of fish was multiplied by the average fish weight (g) (*w*) in each region and divided by 1000 kg to provide an estimated school biomass (equation 5).

$$A = \pi \cdot hlz \tag{2}$$

$$h = \sqrt{\frac{A}{3\pi}} \tag{3}$$

$$V = 4\pi \cdot h^3 \tag{4}$$

$$B = \frac{V \cdot w}{1000000} \tag{5}$$

Nearest neighbour distance (NND)

Meso-scale school clustering patterns in each region were compared using methods developed by Mackinson *et al.* (1999). The nearest neighbour distance (NND) was calculated as the two-dimensional distance from a school to its closest neighbouring school (equation 6). The mean NND ($\overline{NND}$) along approximately 10 km of transect in each region was quantified to assess regional meso-scale clustering patterns.

$$\overline{NND} = \frac{\sum_{1}^{n} NND}{n} \qquad (6)$$

Mackerel school speed, direction, and currents

LSSS school output generated the speed and direction per mackerel school in each region, determined by the first and last ping detections of a school. An improved estimate was developed to give a more realistic view of the direction of each school. This method takes ping-by-ping data to calculate a mean direction and speed. The headings (°), provided by LSSS, were converted into geometric angles relative to the heading of the vessel, and converted back to degrees for the true direction of the school based on a mean value for each ping (Appendix 3). School speed is not referred to in the same sense as swimming speed in this thesis because the currents may influence the actual direction and swimming speed of a school. Therefore, the school speed includes the effect of the prevailing current, whereas the swimming speed is the result of subtracting the current from the school speed (see later).

The current speed (m s^{-1}) and direction (°) were measured continuously onboard M/V "Brennholm" with an RDI Vessel Mount Acoustic Doppler Current Profiler (ADCP) (Teledyne RD Instruments, Inc.) at 75 kHz on narrowband with a 30° beam angle. The current direction (°) and magnitude (m s^{-1}) were collected in five minute averages at 24.5 m depth to be representative of the upper layers of the water column (10 – 40 m) using a default setting of the data collection system VmDas, version 1.46.5 (Teledyne RD Instruments, Inc.) (Nøttestad *et al.* 2010). The ADCP data were reprocessed in VmDas for misalignment by 40.98° throughout the entire survey area because the transducer was changed without performing a new calibration, and there was no bottom track for direction reference due to very deep bottom depths (Nøttestad *et al.* 2010). The reprocessed data was then extracted into data sheets using WinADCP version 1.1.0 (Teledyne RD Instruments, Inc.) to assess whether mackerel schools utilize STST. However, the reprocessed data had unrealistically high current magnitude values, therefore, the magnitude values from the raw data were coupled with the direction from the reprocessed data as a representative of the local prevailing currents.

The active swimming speed by the mackerel schools without the influence of the local prevailing currents was found by decomposing the vectors of both the mackerel schools and the local prevailing current. The x and y vectors of the average local current along each transect was subtracted from the x and y vectors of the schools. The corresponding schools were matched with the local current based on the time at which they were sampled. The resultant was considered to be the active swimming speed without the influence of the local current.

SONAR ray-trace

Various physical conditions during a survey may influence the accuracy of measurements from acoustic instruments. Adverse weather conditions and strong thermoclines can result in inaccurate acoustic measurements (Aglen 1994; Simmonds and MacLennan 2005; Nøttestad *et al.* 2010; Bernasconi *et al.* 2012). LYBIN is an acoustic ray-trace simulator of how acoustic waves propagate through the water column (Norwegian Research Defence Establishment/Forsvarets Forskningsinstitutt (FFI) Facts 2012; Nøttestad *et al.* 2010). A LYBIN ray trace was performed and combined with the CTD data from a station near the SE region (CTD station no. 29) to compare the depth results provided by the SONAR and those which were reflected on the echogram to see if acoustic ray bending occurred in this area of the survey.

Biological data

Mackerel length and weight

The cruising speed between predetermined stations was predominantly between 10.0 - 12.0 knots during the survey, with the speed was reduced to 4.2 - 5.3 knots during standardized pelagic trawling close to the surface for 30 minutes after a CTD profile and plankton station. This duration was reduced a couple of times if large schools or aggregations of fish were detected on the trawl sonde (Nøttestad *et al.* 2010). Pelagic sampling was done with a large pelagic trawl towed 160 - 200 m behind the vessel with a vertical opening between 30 - 35 m and spread 55 - 65 m (Nøttestad *et al.* 2010; 2012). Trawl data provided information on the length and weight of NEA mackerel based on subsamples of 100 individuals per trawl; and as verification that mackerel were in the area of scrutinized acoustic data. The fish were sorted by species onboard after trawling and a total weight was recorded using Fishmeter measuring tools (Scantraal) (Øvredal and Totland 2002).

A subsample of 100 individuals from each haul was used to calculate the mean total length (nearest 0.5 cm below) and wet weight (nearest gram below) of the catch (see Mjanger *et al.* 2010). Fulton's Condition Factor (K) was calculated to assess mackerel condition (equation 7) (Ricker 1975).

$$K = 100 \cdot \frac{W}{L^3} \tag{7}$$

Plankton sampling

Zooplankton sampling was performed along with the CTD stations, which were distributed approximately every 60 nmi. A WP-2 net (56 cm in diameter) with a 180 µm mesh size was towed from 200 m depth to the surface at 0.5 m s^{-1} (see Fraser 1966). The sampling range was chosen based on the depth ranges of mackerel and other pelagic species which were the focus of the survey. The sampling range from 0-200 m depth is also international standard for WP-2 net hauls in ICES. While aboard the vessel, each sample was divided in two fractions: 1) taxonomic analyses (taxonomic species, size), and 2) biomass estimates. On board, the samples were split into two equal parts, one was preserved with formaldehyde and the second was to be dried. Prior to drying, the samples were divided into size fractions (<1000 µm, 1000-2000 µm, and >2000 µm) by sieves filtering mesh sizes 2000 µm, 1000 µm and 180 µm, weighed, dried, and weighed again at the institute laboratory after the survey. The result of the >2000 µm fraction was identified, and depending on the species group the organisms were length measured and the various groups were transferred to trays for drying, and then weighed (Nøttestad *et al.* 2010).

Marine mammal observations

Marine mammal observations were also used for ecological interpretation. Two observers were constantly on watch during daylight hours to note the species, time and location of marine mammals sighted. The priority observation periods were during the cruising periods from one trawl station to the next (Palka and Hammond 2001; Lawson and Gosselin 2009; Nøttestad *et al.* 2010).

Statistical analysis

The statistical program R version 2.15.1 was used for all statistical analyses and plotting. The Shapiro-Wilk normality test was used to test normality in the data set. Parametric tests (linear regression analysis, analysis of variance (ANOVA) and Tukey HSD were used in this analysis. Tukey HSD was used to compare school parameters (depth, swimming speed, NND and biomass) between regions. Non-parametric regression models (histograms) were used in cases when there was deviation from normal distribution. All of the statistical tests assumed 0.05 significance.

Results

Temperature

In general, the NW experienced the coldest sub-surface sea temperatures, and the SE had the warmest. The sea temperature ranged from 4.8° C to 10.3° in the four regions combined (Figure 3). In the NW, the 8º C isotherm occurred at a shallower depth (13 m) compared to the other regions (Figure 3). In the NE and SW, the 8º C isotherm was at 26 m and 28 m, respectively, whereas in the SE it occurred at 47 m depth. The temperature also decreased more rapidly with depth in the NW compared to the other three regions. The temperature distribution throughout the Norwegian Sea mapped below illustrates the decrease in temperature both from the coast towards the Arctic front and from 10 - 50 m, particularly in the western Norwegian Sea (Figure 4, Nøttestad *et al.* 2010).

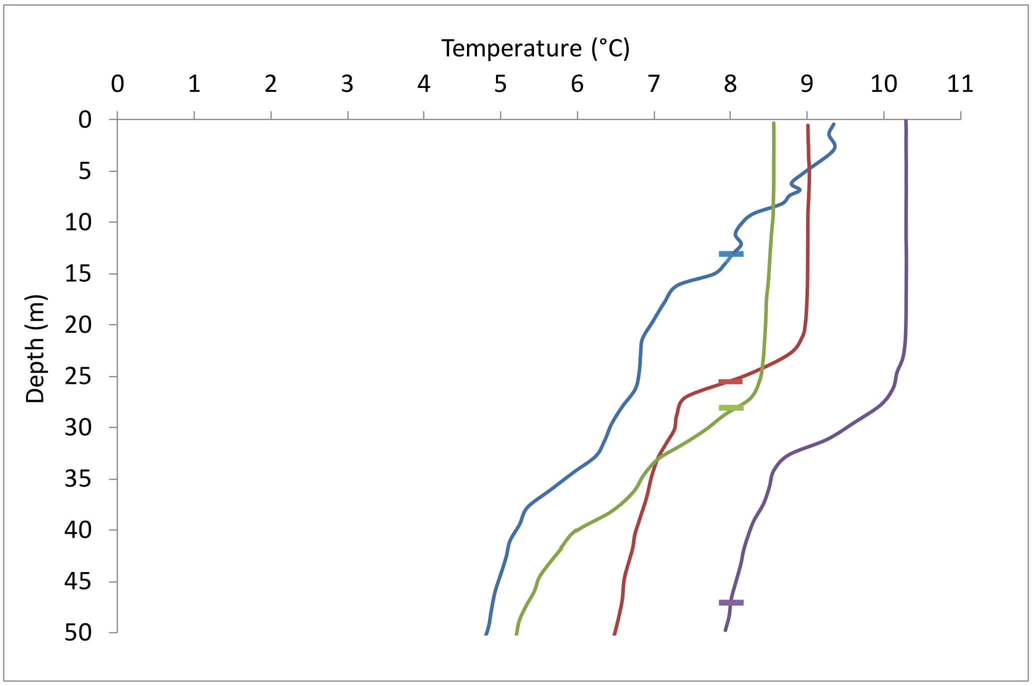


Figure 3. Temperature (°C) profiles from 50 m depth to the surface in the four study regions. The horizontal lines indicate the depth at which the sea temperature reaches 8º C in each region (blue = NW; red = NE; green = SW; purple = SE).

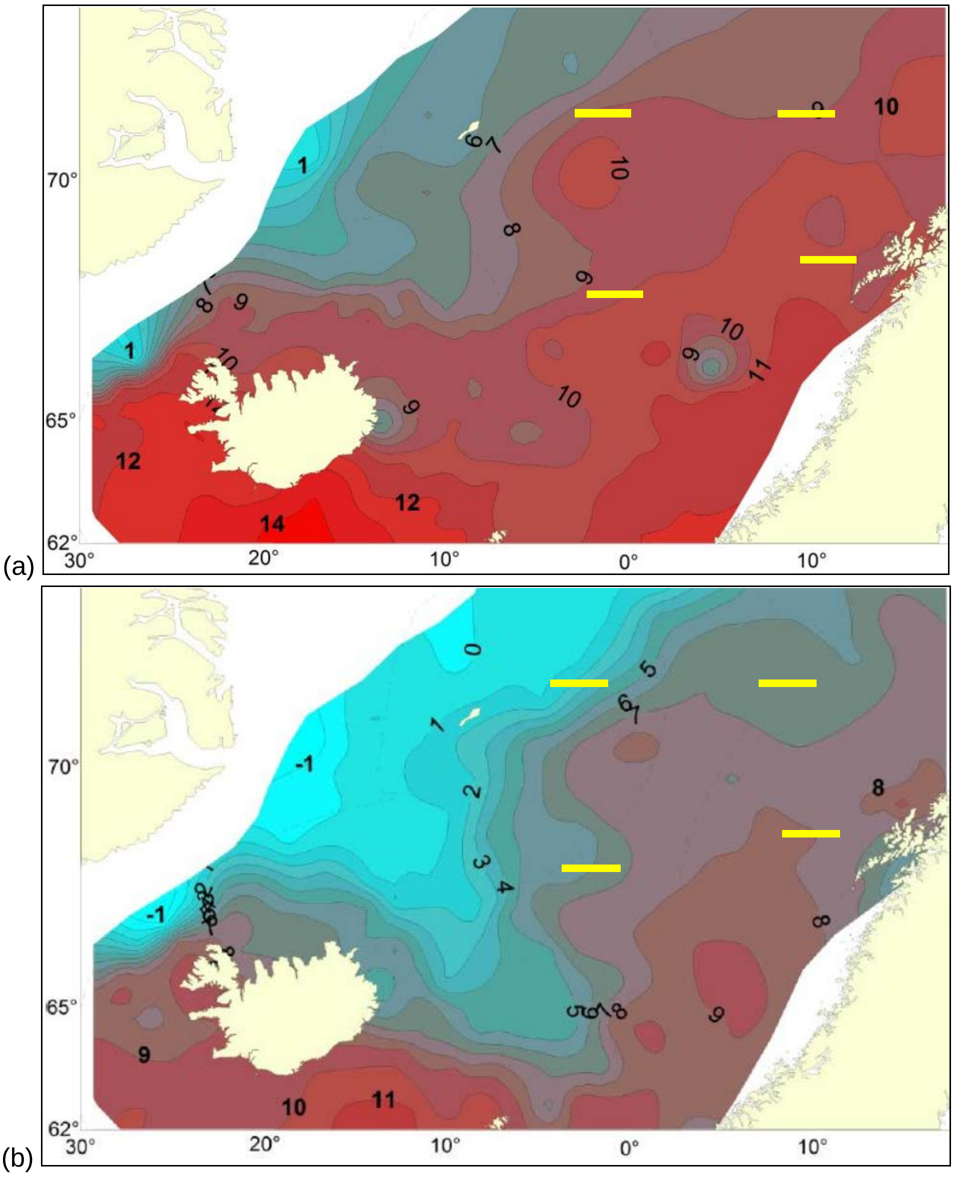


Figure 4. Mapped temperature (°C) in the NE Atlantic from the July-August 2010 ICES Ecosystem Survey at 10 m (a) and 50 m (b) depth (Nøttestad *et al.* 2010). The yellow lines represent the general geographic location of the sampling transects.

Acoustic data

A total of 276 selected mackerel schools were tracked with a high-frequency multibeam omnidirectional SONAR in this study. From those schools, 251 schools, which occurred during daytime hours, comprised the main comparisons of the regions: 62 NW, 52 NE, 66 SW, and 60 SE. For the diurnal analyses, 36 additional schools during night hours in the NE were compared with the 52 schools from the daytime transect. The data set did not have normal distribution; therefore a log transformation was performed.

Depth distribution

The depth distribution of NEA mackerel school mean depth was within the top 40 m of the water column, the mean depths ranged from 9 - 39 m between the four regions (Figure 5). The average mean school depth in the NW, NE and SE were very similar at 20, 22 and 19 m, respectively, but the average mean school depth in the SW (26 m) was significantly deeper than the other three regions (Tukey HSD, $p < 0.005$). The NW schools occurred from 12 - 29 m; a smaller distribution compared to the other regions, which all had maximum mean depths deeper than 35 m.

The majority of the schools in the NW were distributed below the 8° C isotherm, and the temperature at the maximum school mean depth (29 m) was 6.8° C (Figure 5). The schools in the NE and SW had roughly the same maximum school mean depth, and the 8° C isotherm occurred between 26 - 28 m in both regions. The majority of schools occurred above the depth where sea temperature reached 7° C, and all schools occurred in waters warmer than 6° C.

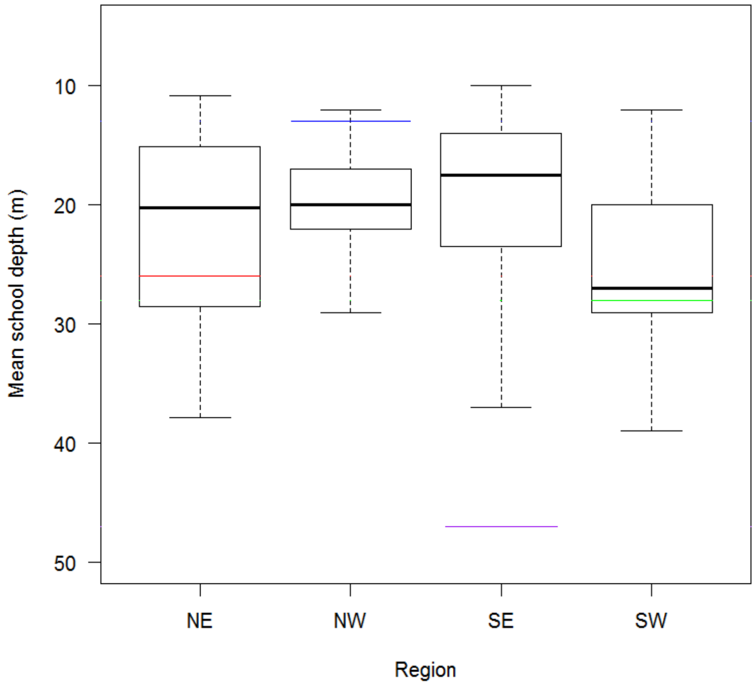


Figure 5. Box and whisker plot of mackerel school mean depths (m) in the four study regions. The coloured lines represent the depth of the 8º C isotherm in each region (blue = NW, red = NE, green = SW, purple = SE). The bold line represents the median value, the box is the midspread (including the first and third quartiles), and the whiskers are the minimum and maximum values.

Mackerel school biomass

Estimated school biomass ranged from 68 kg to 10538 kg between the four regions combined (Figure 6). The schools in the northern regions had greater mean biomass than in the southern regions (ANOVA, $p < 0.01$). The SW region had the lowest average biomass between the regions (1352 kg), as well as the smallest distribution of biomass (142 - 3797 kg) (Tukey HSD, $p < 0.01$).

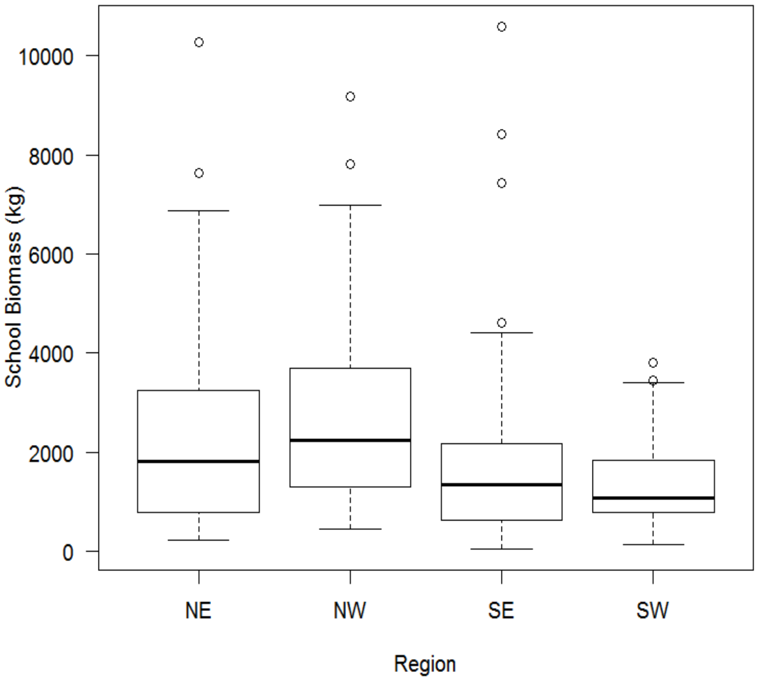


Figure 6. Estimated relative biomass (kg) of mackerel schools per region. The bold line represents the median value, box is the midspread (including the first and third quartiles), the whiskers are the minimum and maximum values, and the circles are outliers.

Nearest neighbour distance (NND)

The distribution of the tracked schools along the transects were analysed using the method developed by Mackinson *et al.* (1999). The data revealed that schools were anywhere from 39 - 1286 m from its nearest neighbour along a 10 km section (Table 2). More schools were detected along in the SW and NE (night) segments along the 10 km stretch compared to the other segments (Table 2). The SW schools had smaller $\overline{NND}$ than the other regions (ANOVA, p < 0.001). A smaller $\overline{NND}$ indicates schools are closer together, whilst a larger $\overline{NND}$ illustrates greater distance between one school and its nearest neighbour.

Table 2. Mean Nearest Neighbour Distance ($\overline{NND}$) of a transect segment approximately 10 km long of the scrutinized transects in each region; including: number of schools, mean, and range of $\overline{NND}$ values along the segment.

Region	Latitude	Longitude	Schools (*n*)	$\overline{\text{NND}}$ (*m*)	NND ranges (*m*)
NW	71° 14’ 15.72” N 71° 14’ 5.23” N	2° 4’ 1.06” W 1° 48’ 6.20” W	27	274	94 - 1286
NE (day)	71° 12’ 10.94” N 71° 11’ 44.64” N	7° 41’ 8.65” E 7° 58’ 7.39” E	27	254	74 - 586
NE (night)	71° 11’ 53.07” N 71° 11’ 27.75” N	9° 28’ 54.01” E 9° 45’ 12.48” E	36	244	59 - 1135
SW	67° 58’ 1.36” N 67° 57’ 42.14” N	4° 2’ 56.53” W 3° 50’ 16.31” W	46	194	39 - 429
SE	68° 43’ 34.85” N 68° 43’ 35.66” N	10° 29’ 56.94” E 10° 45’ 33.12” E	26	385	42 - 1151

Mackerel school speed, direction and currents

The mean speed is the net school speed resulting from active swimming and the influence of the prevailing current. The average mean speed in all of the areas combined was 1.44 m s^{-1} (Figure 7), approximately 4.24 body lengths per second (B.L. s^{-1}). Minimum mean school speed was 0.04 m s^{-1}, the maximum was 7.2 m s^{-1}, and the majority of the schools were moving between 0.72 and 1.79 m s^{-1}. In general, the schools in the north had a slower average mean speed than those in the south (ANOVA, $p < 0.01$). The SW schools moved significantly faster than those in the NW (Tukey HSD, $p < 0.001$) and NE (Tukey HSD, $p < 0.005$). The SW schools also displayed a wider range of mean school speeds compared to the NW schools.

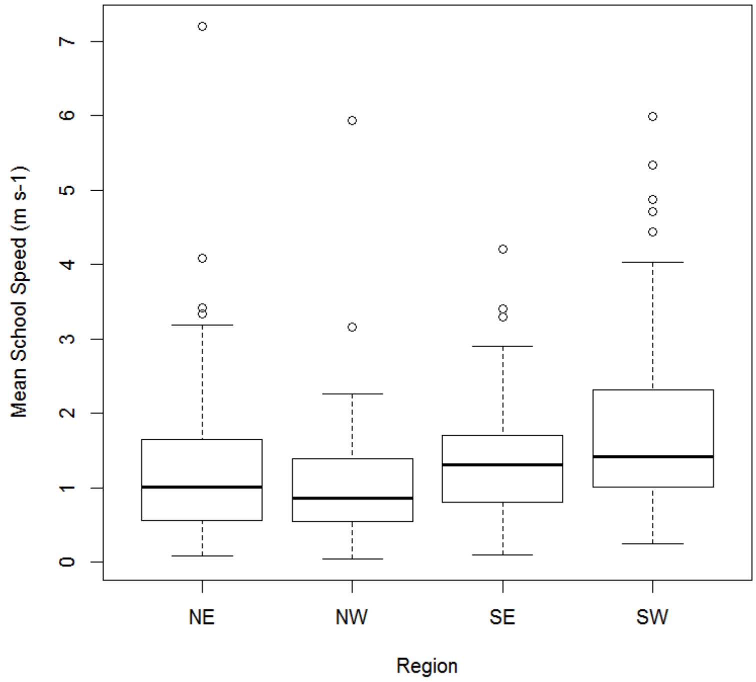


Figure 7. Range of observed mean school speeds (m s^{-1}). The bold line represents the median speed value, the box is the midspread (including the first and third quartiles), the whiskers are the minimum and maximum values, and the circles are outliers.

School direction is first illustrated as rose plot histograms using the free software Rose.Net, version 0.10 (Todd A. Thompson Software 2012, http://mypage.iu.edu/~tthomps/programs/html/tntrose.htm), and also displayed as feather plots. The rose plot histograms illustrate class intervals of 15° for the mean school direction (°) in each region (Figures 8-11 a). Feather plots were also used to illustrate the school direction (arrow direction) and speed/velocity (arrow length) (Figures 8-11 b). In the NW, NE and SE, the mean direction was north with the prevailing current (Figures 8, 9 and 11 b). However, in the SW the mean direction of the schools was to the south (Figure 10). The current speed in the NW, NE and SE was approximately 0.35 m s^{-1} in a northward direction (Figures 8, 9 and 11 c), and about 0.32 m s^{-1} in the SW in a southward direction (Figure 10 c). The current data in the SW may suggest a meso-scale oceanic eddy (Figure 10 c).

Figures 8-11 d illustrate the school speed minus the effect of the current, which is referred to as the swimming speed. The minimum and maximum speeds (or velocities) are presented as a scale of reference. The results illustrate faster school speeds for schools swimming with the currents, and slower speeds for those actively swimming against the current at that time. Most of the schools in all of the regions were swimming with the prevailing local current, thus resulting in a slightly reduced swimming speed because of the prevailing current.

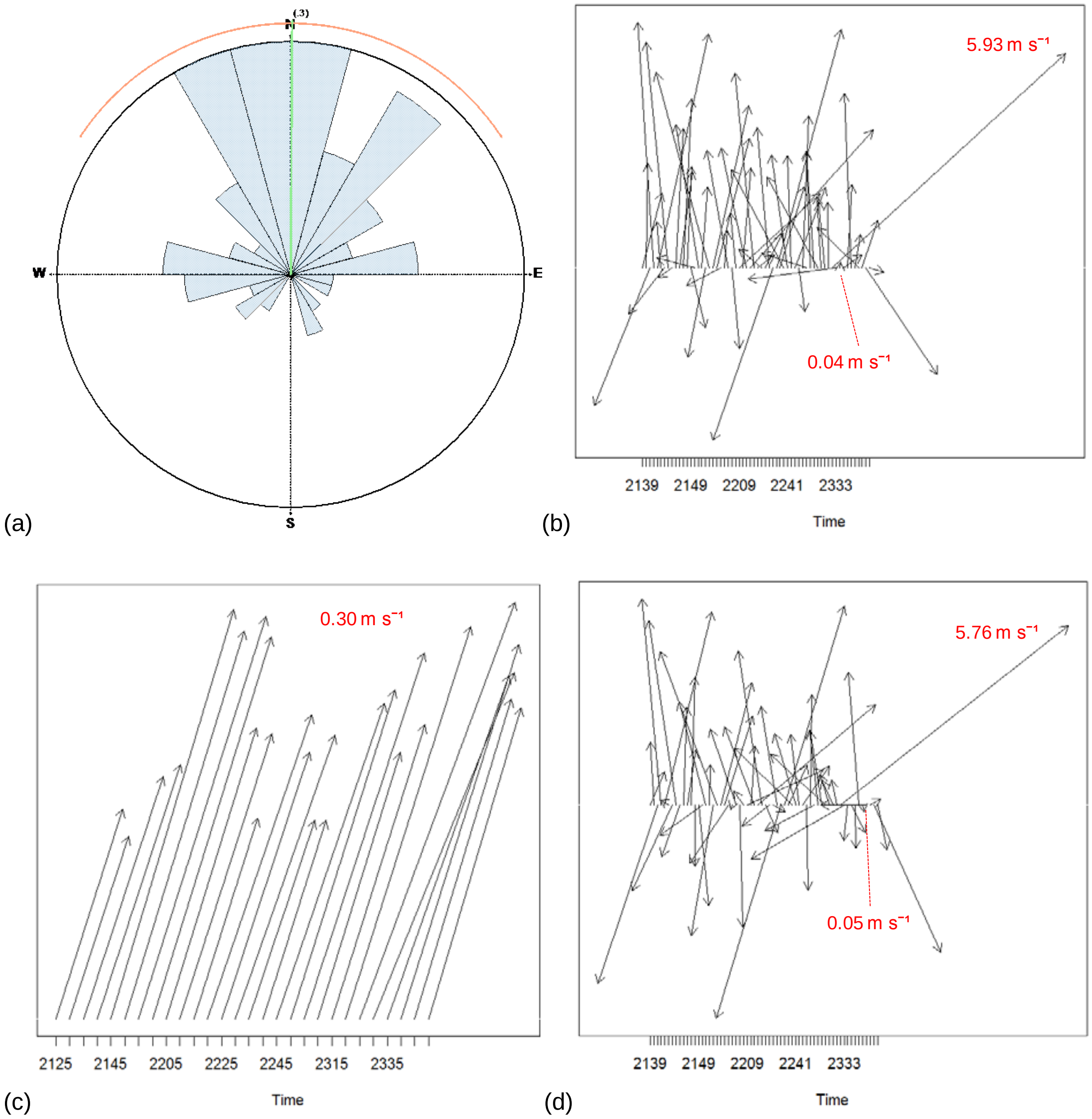


Figure 8. NW mackerel school school directions are presented on a rose plot histogram; the green line represents the mean and the orange line outside the circle is the standard deviation (maximum value of axis = 7) (a). Feather plots illustrate the school direction and speed (b), current direction and magnitude (c), and the school swimming speed and direction without the influence of the current (d). Speed and direction vectors are represented as arrow length and angle. The minimum and maximum school speeds and mean current magnitude for the region are in red.

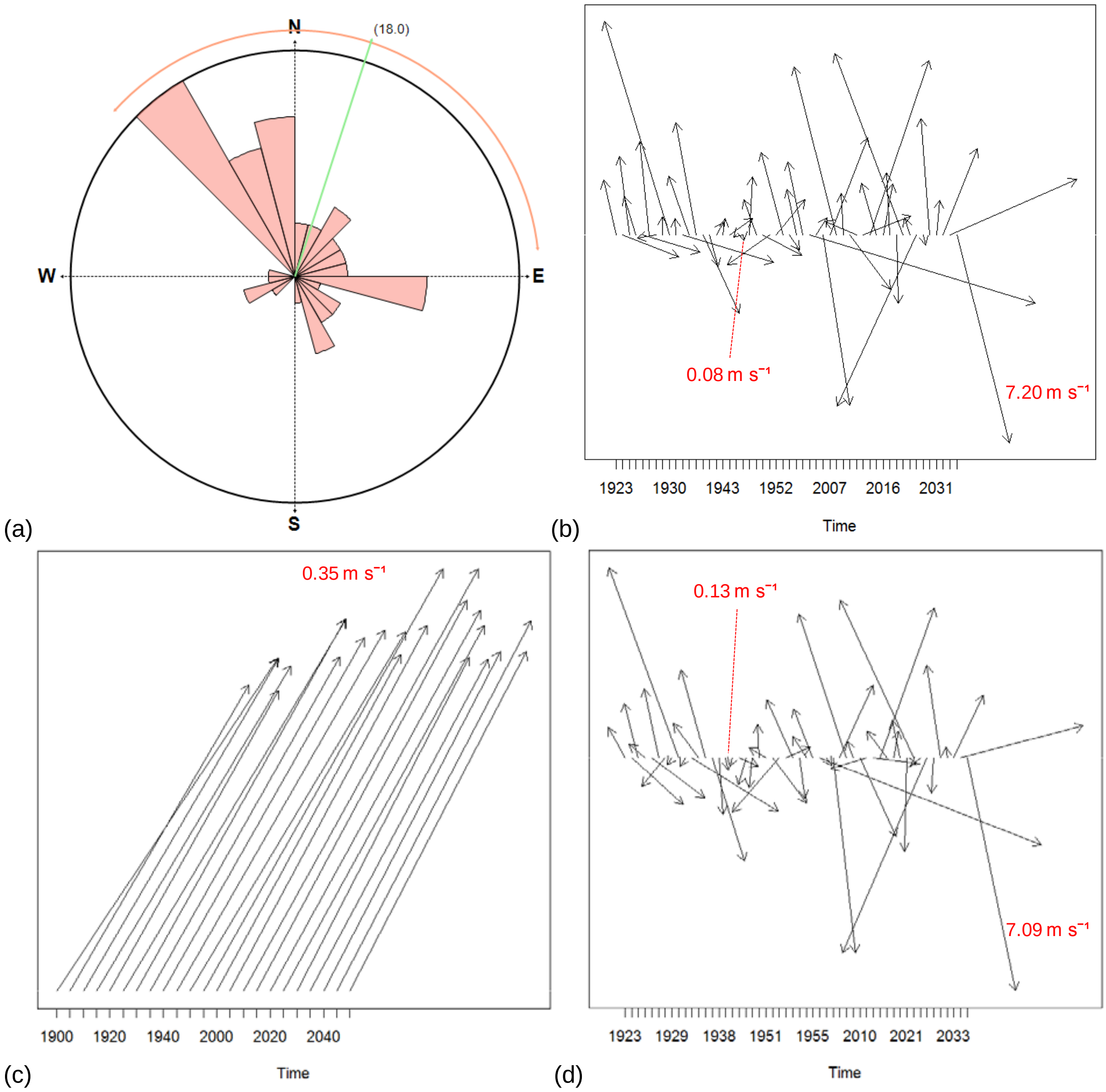


Figure 9. NE mackerel school directions are presented on a rose plot histogram; the green line represents the mean and the orange line outside the circle is the standard deviation (maximum value of axis = 9) (a). Feather plots illustrate the school direction and speed (b), current direction and magnitude (c), and the school swimming speed and direction without the influence of the current (d). Speed and direction vectors are represented as arrow length and angle. The minimum and maximum school speeds and mean current magnitude for the region are in red.

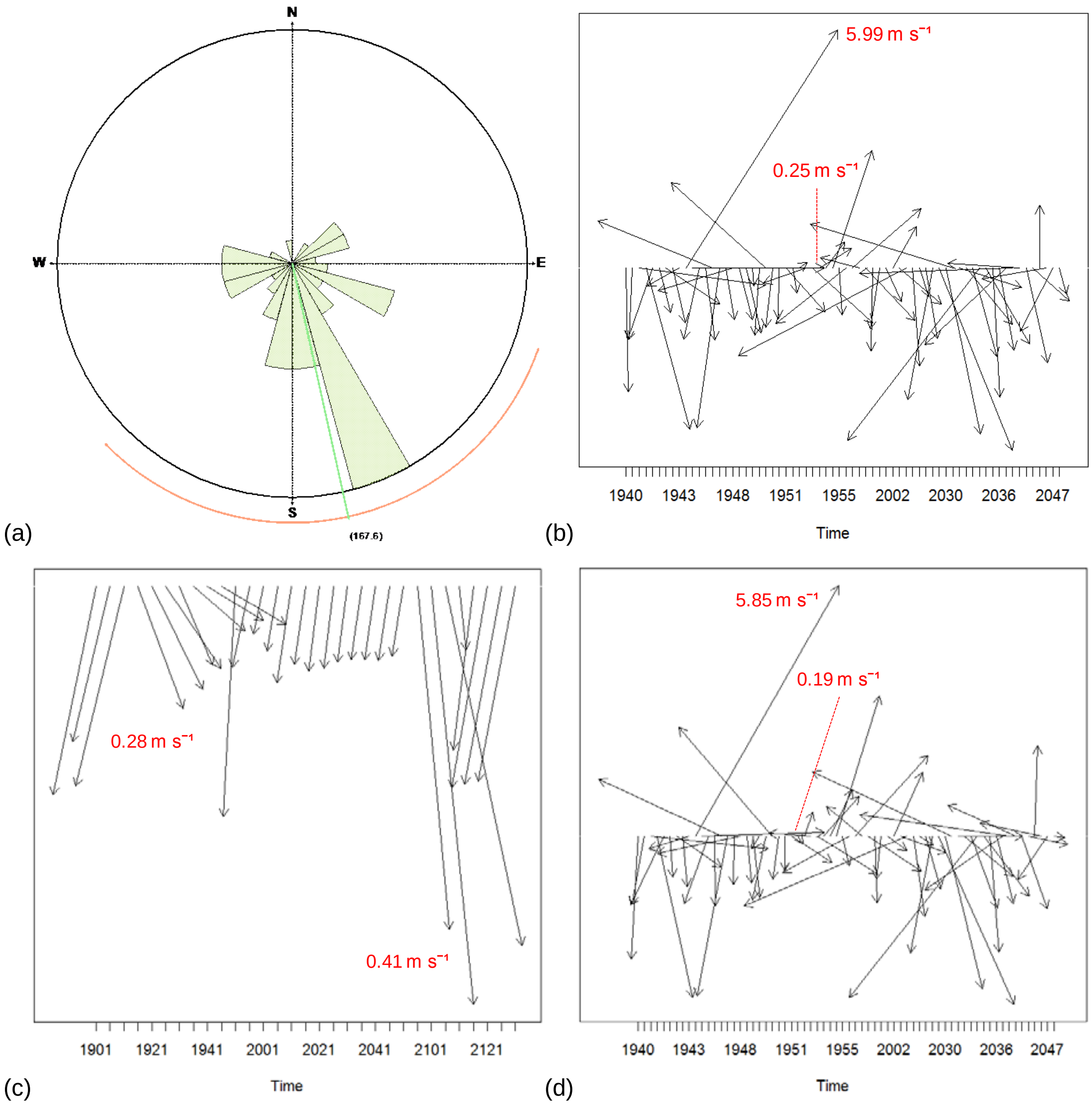


Figure 10. SW mackerel school directions presented on a rose plot histogram; the green line represents the mean and the orange line outside the circle is the standard deviation (maximum value of axis = 13) (a). Feather plots illustrate the school direction and speed (b), current direction and magnitude (in this case, split into separate segments of mean direction and magnitude) (c), and the school swimming speed and direction without the influence of the current (d). Speed and direction vectors are represented as arrow length and angle. The minimum and maximum school speeds and mean current magnitude for the region are in red.

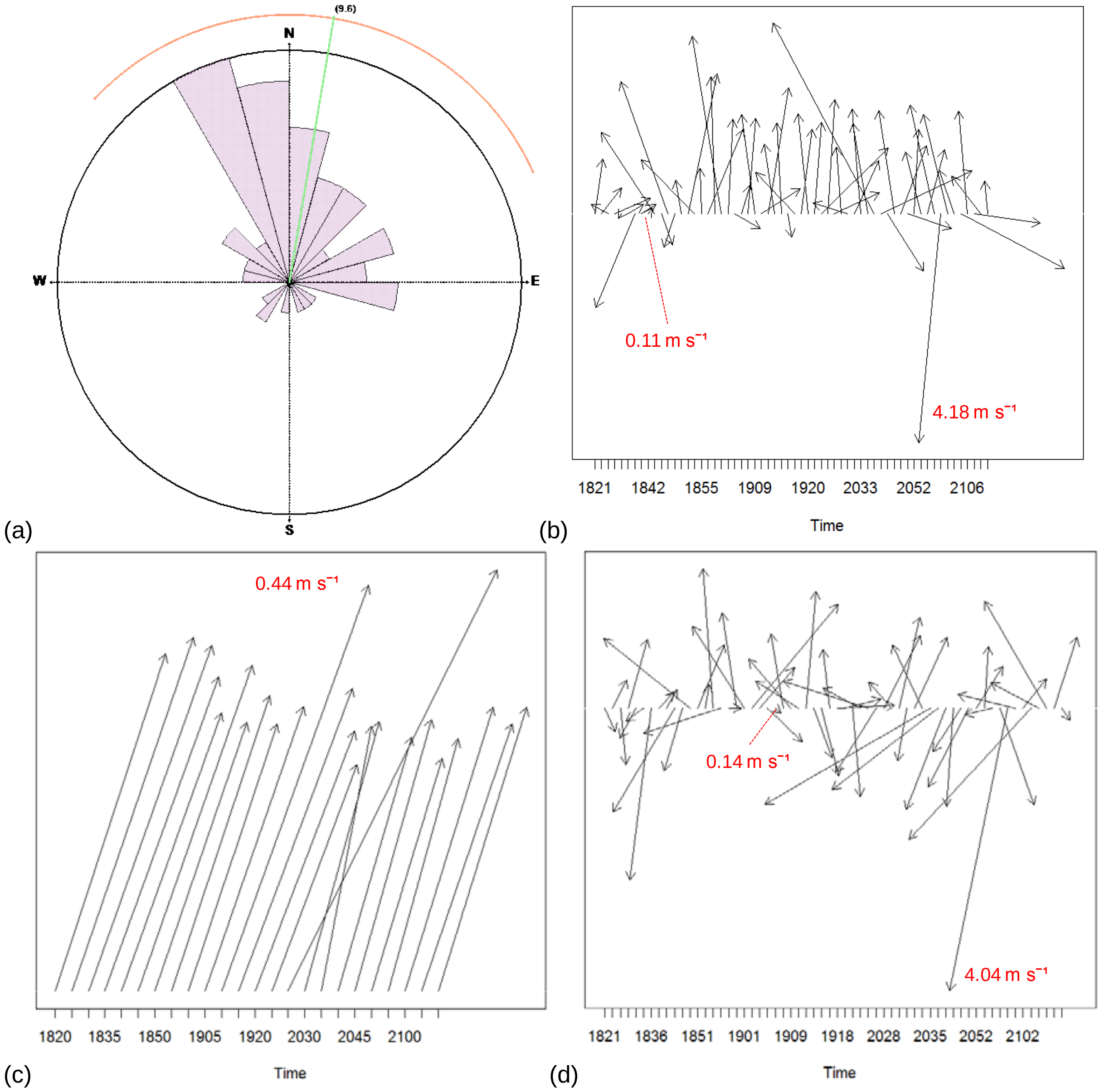


Figure 11. SE mackerel school directions are presented on a rose plot histogram; the green line represents the mean and the orange line outside the circle is the standard deviation (maximum value of axis = 9) (a). Feather plots illustrate the school direction and speed (b), current direction and magnitude (c), and the school swimming speed and direction without the influence of the current (d). Speed and direction vectors are represented as arrow length and angle. The minimum and maximum school speeds and mean current magnitude for the region are in red.

Diurnal behaviour

The mean school depth was deeper at night than during the day (ANOVA, $p < 0.001$) (Figure 12). The average mean depth during the day was 22 m (median 20 m), and 25 m at night (median 27). The depths during the day ranged from 11 - 38 m and from 9 - 36 m at night.

The biomass estimates of the tracked schools were also larger along the daytime transect than the night transect (ANOVA, $p < 0.001$) (Figure 13). The average school biomass during the night transect was 1920 kg, compared to 4150 kg during the day transect. The range of school biomass estimates was more variable during the day compared to at night. There were no observed diurnal differences in school speed, direction or NND.

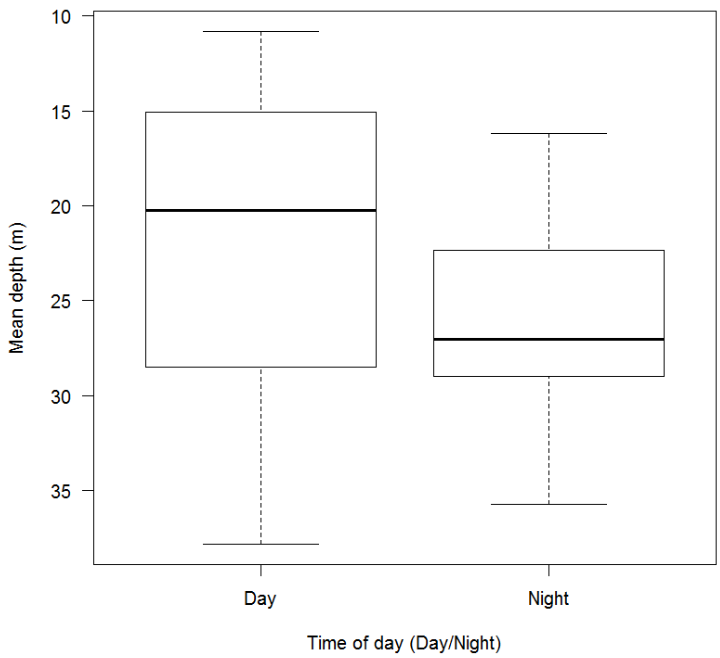


Figure 12. Mackerel school mean depths (m) in the NE (71° 15’ N) at daytime (*N* =52; 19:26-20:23 31/07/2010, 7° 50’ 51” E) and night (*N* = 36; 23:39 31/07/2010 – 00:08 01/08/2010, 9° 45’ 12” E). The bold line represents the median depth, the box is the midspread (including the first and third quartiles), and the whiskers are the minimum and maximum values.

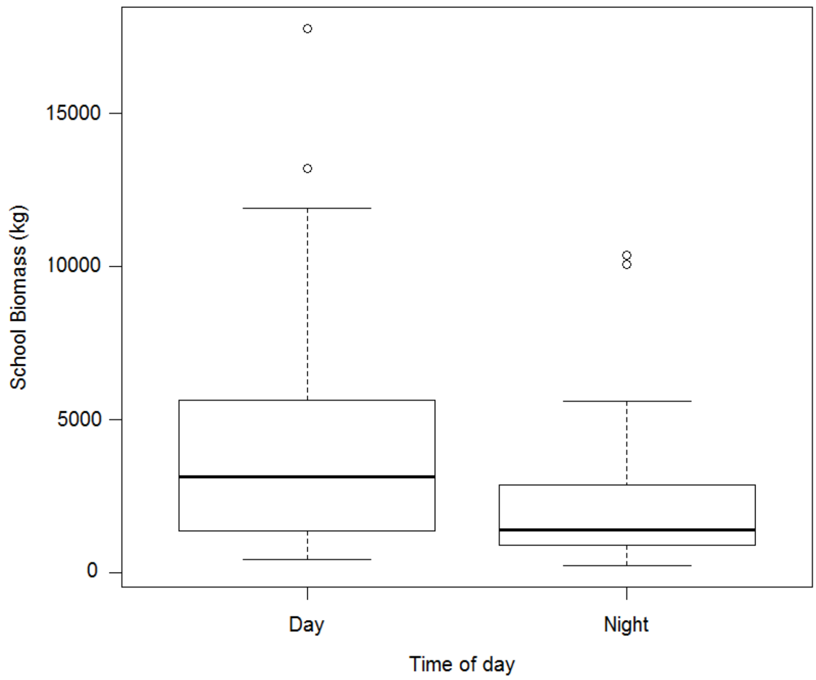
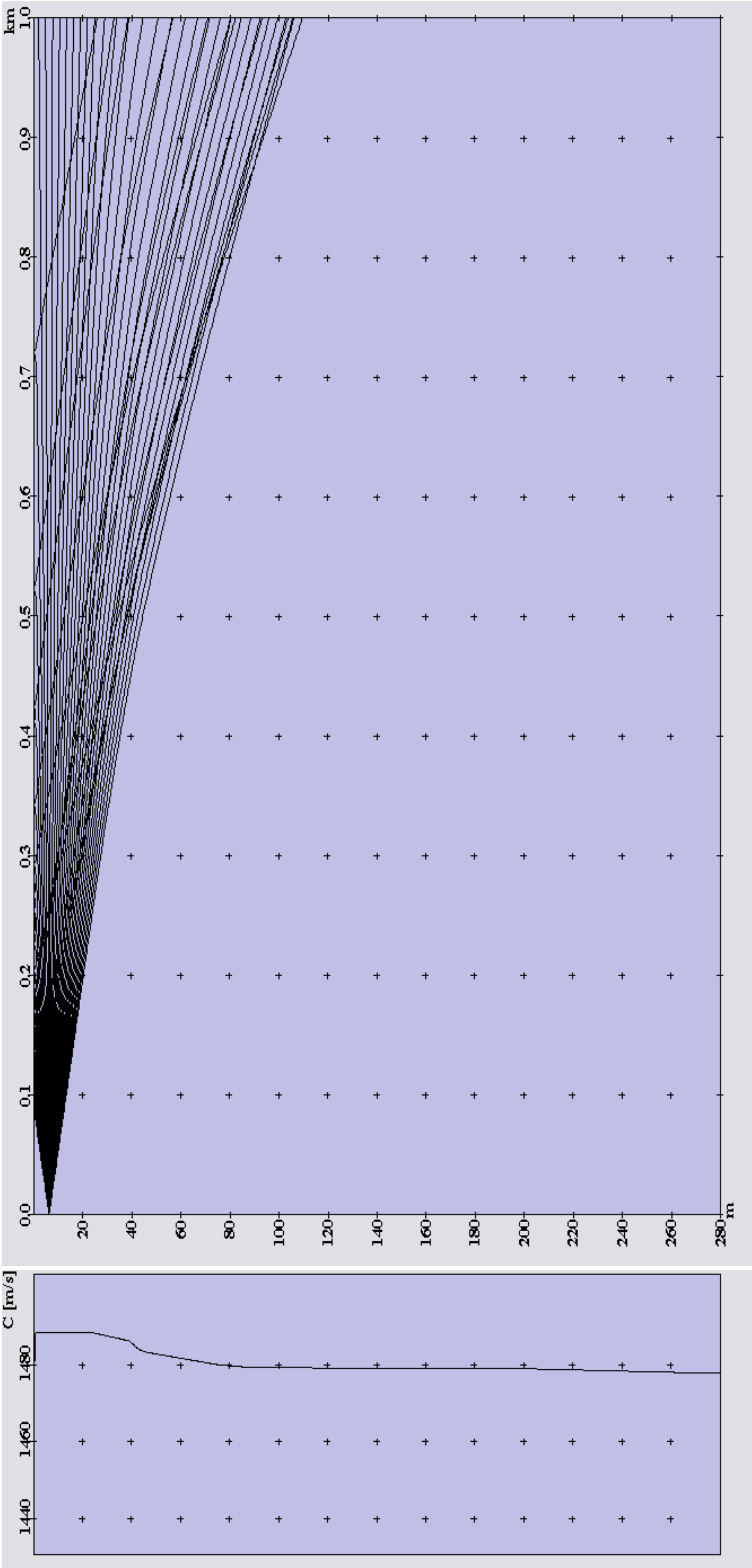


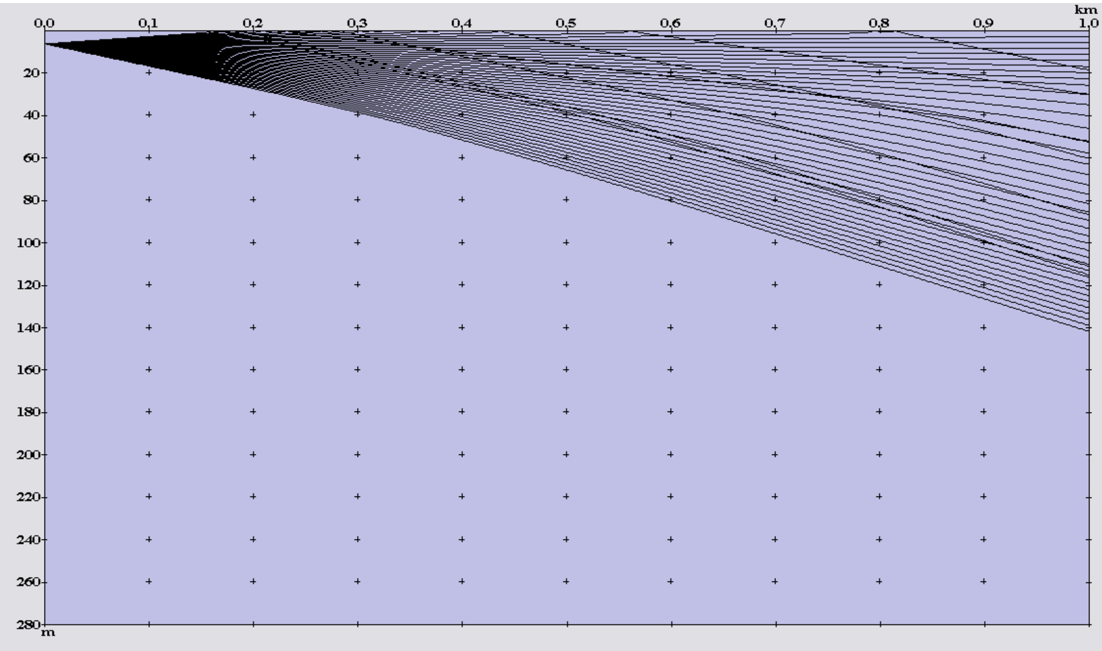
Figure 13. Estimated school biomass (kg) in the NE (71° 15' N) at daytime (*N* =52; 19:26-20:23 31/07/2010, 7° 50' 51" E) and night (*N* = 36; 23:12 31/07/2010 – 00:08 01/08/2010, 9° 45' 12" E). The bold line represents the median biomass, the box is the midspread (including the first and third quartiles), the whiskers are the minimum and maximum values, and the circles are outliers.

SONAR ray-trace

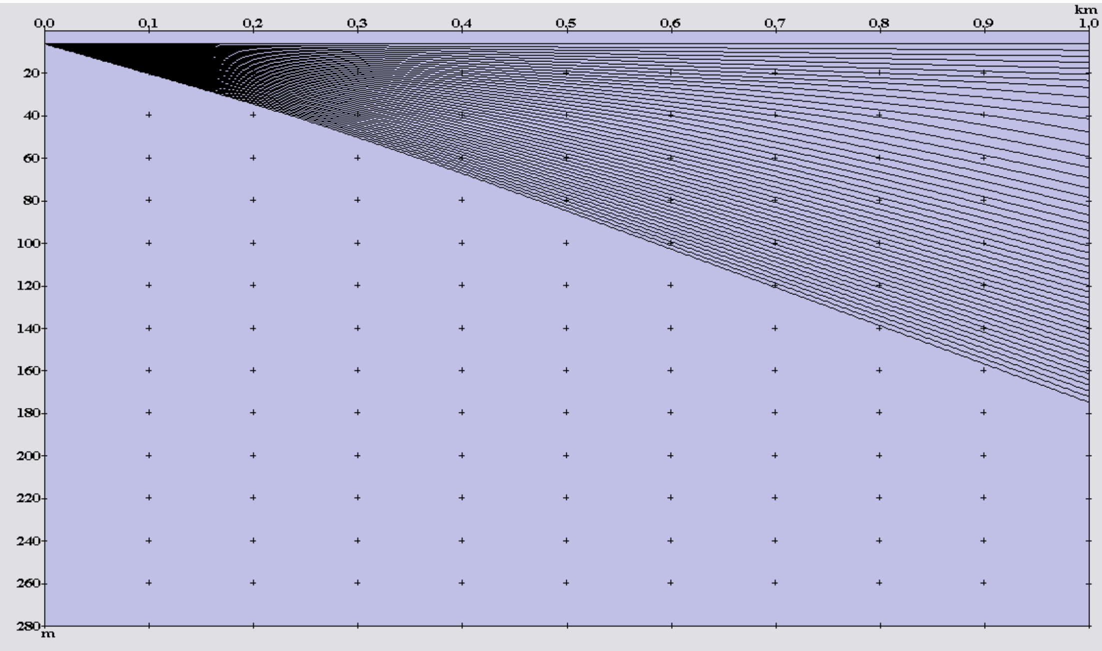
A LYBIN ray trace was performed using the CTD data from a specific station in the SE region (CTD station no. 29) where the schools were particularly difficult to detect. It illustrates the beam width at 300 m distance from the vessel, the beam stretched from approximately 30 m to the surface at 0° tilt angle (Figure 14 a). At 2° tilt, the beam spreads from 0 to 40 m depth at 300 m distance from the vessel (Figure 14 b). And at 4 ° tilt, the beam reaches approximately 50 m depth (Figure 14 c). Furthermore, at distances up to 1 km from the vessel, the beam spreads from the surface to deeper than 100 m. Due to the shape of the acoustic beam, sampling volume increases with distance from the vessel (Fréon *et al.* 1992). It also illustrates that there was no strong thermocline in this region to cause acoustic ray bending.

(a)





(b)



(c)

Figure 14. Sound speed profile (m s^{-1}) (a, left) and ray trace simulation for a CTD station in the SE region for the Simrad SH80 unit operating at 116 kHz at 0° (a, right), -2° (b), and -4° (c) tilt angle.

Biological data
Spatial distribution

Mackerel were present in most of the trawl catches from the predetermined stations throughout the survey period, and were dominating along the coast of Norway and central Norwegian Sea samples (Figure 15; Nøttestad *et al.* 2010). NSS herring dominated trawl samples west of 4° W and north of 72° N. The spatial overlap between mackerel and herring occurred mainly in the outskirts including southern, southwestern, and northern parts of the Norwegian Sea (Nøttestad *et al.* 2010). Blue whiting, salmon, and other (e.g. lumpsucker) were not used in this study though depicted in the figure.

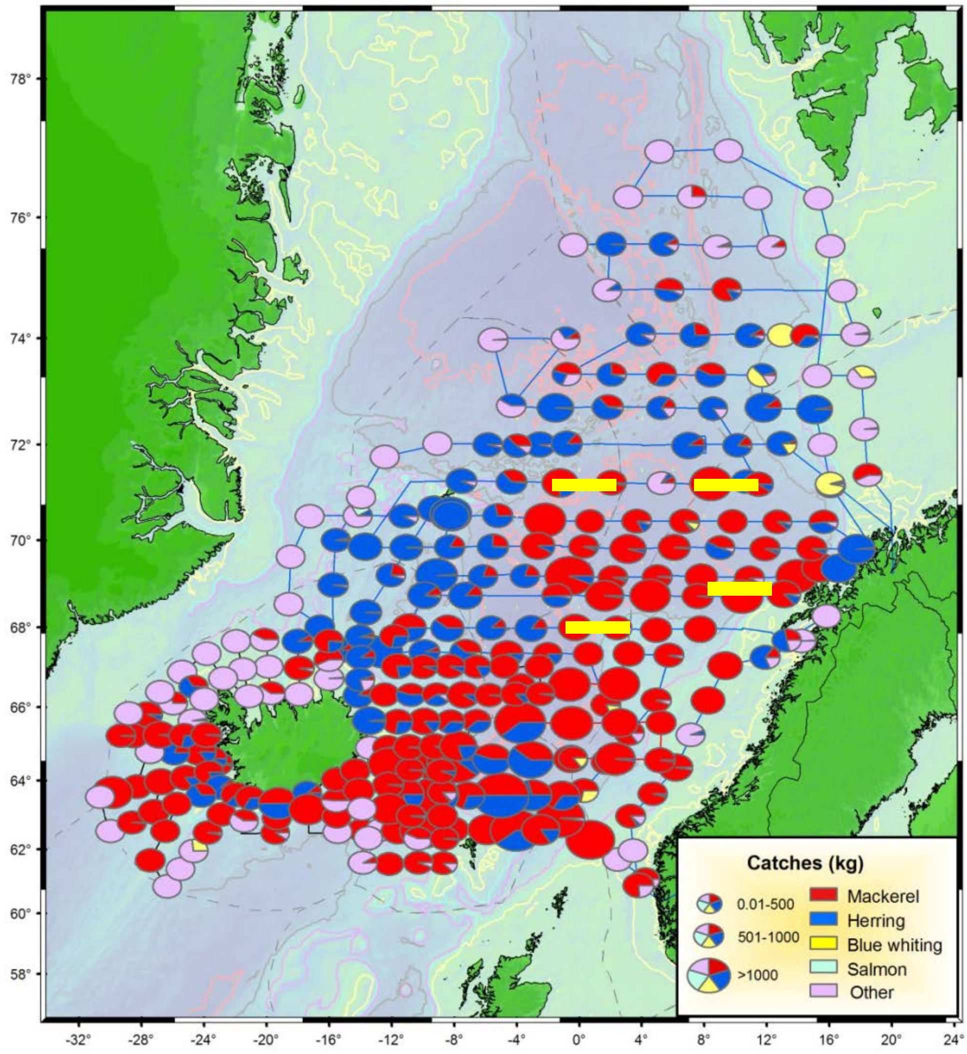


Figure 15. Distribution and spatial overlap between mackerel (red), herring (blue), blue whiting (yellow) and salmon (violet) from M/V “Libas”, M/V “Brennholm”, M/V “Finnur Fridi” (Faroe Islands) and M/V “Arni Fridriksson” (Iceland) in the Norwegian Sea, 15 July - 20 August 2010 (Nøttestad *et al.* 2010). The yellow lines represent the general area of each transect, not the exact transect location and length.

Mackerel length and weight

The biological data on NEA mackerel are from the pelagic trawl station, directly after the CTD and plankton stations, which was closest to the relevant transect in each region. There was a significant difference in the size (length and weight) of NEA mackerel between the north and the south (ANOVA, p <0.01) (Figure 16). The mackerel in the NE region were the largest, and those in the SW were the smallest (Figure 16, Table 3). In general, the mackerel condition (K) was higher in the south than in the north (ANOVA, $p < 0.01$). In particular, K was significantly higher in the SW than in the NW (Tukey HSD, $p < 0.05$) (Table 3). The 2005- and 2006-year classes dominated the mackerel population in the Norwegian Sea and constituted 50% in 2010 (Nøttestad *et al.* 2010).

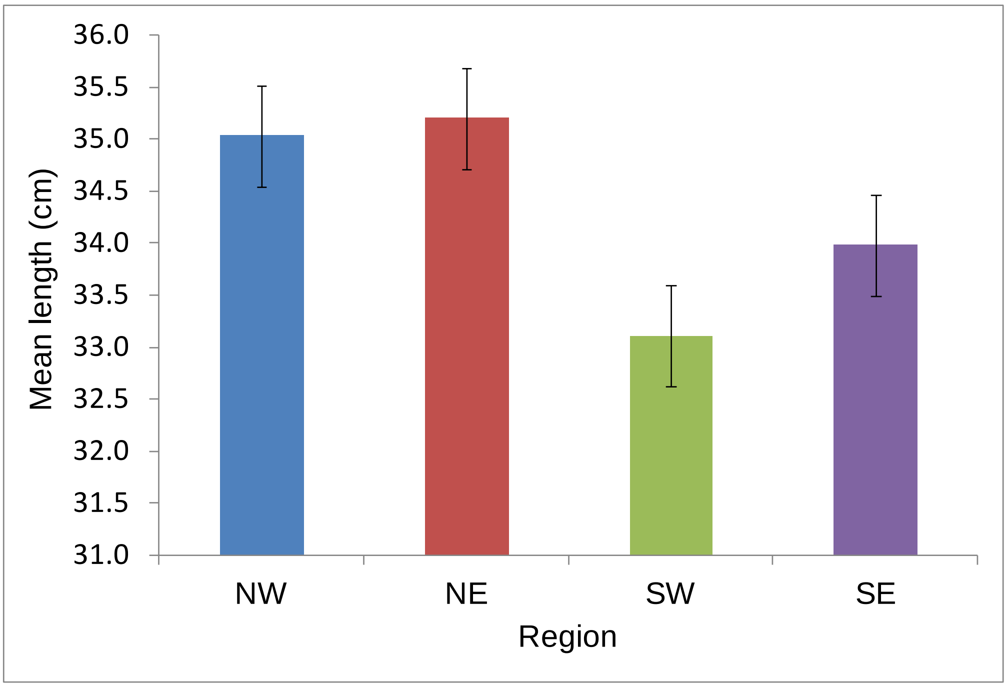


Figure 16. Mean length (±SE) (cm) of NEA mackerel in the study areas.

Table 3. Mean length (cm), weight (g) and condition factor (K) with standard deviation (±SD) based on a sub sample of 100 individuals from each of the study areas.

Region	Mean Length	Mean Weight	K
NW	35.0 ±1.5	393.5 ±51.2	0.91 ±0.07
NE	35.2 ±1.8	412.3 ±65.1	0.94 ±0.06
SW	33.1 ±1.6	353.4 ±40.9	0.97 ±0.08
SE	34.0 ±2.4	372.4 ±77.8	0.94 ±0.08

Plankton biomass

The plankton results are based on one sampling station nearest to the relevant acoustic transect. The NW region had the highest biomass of plankton per square metre (6.52 g m²), and the SW had the lowest (3.08 g m²) (Figure 17). Small plankton (<1000 µm) was present in all regions, and dominated the NW and SE samples (Figure 17). Medium plankton (1000-2000 µm) was also present in all regions, and comprised of the majority fraction in the NE sample. Large plankton (>2000 µm) was present in the NE and SW, and a very small amount in the SE (0.016 g m²). The SW did not have one particular dominant size fraction.

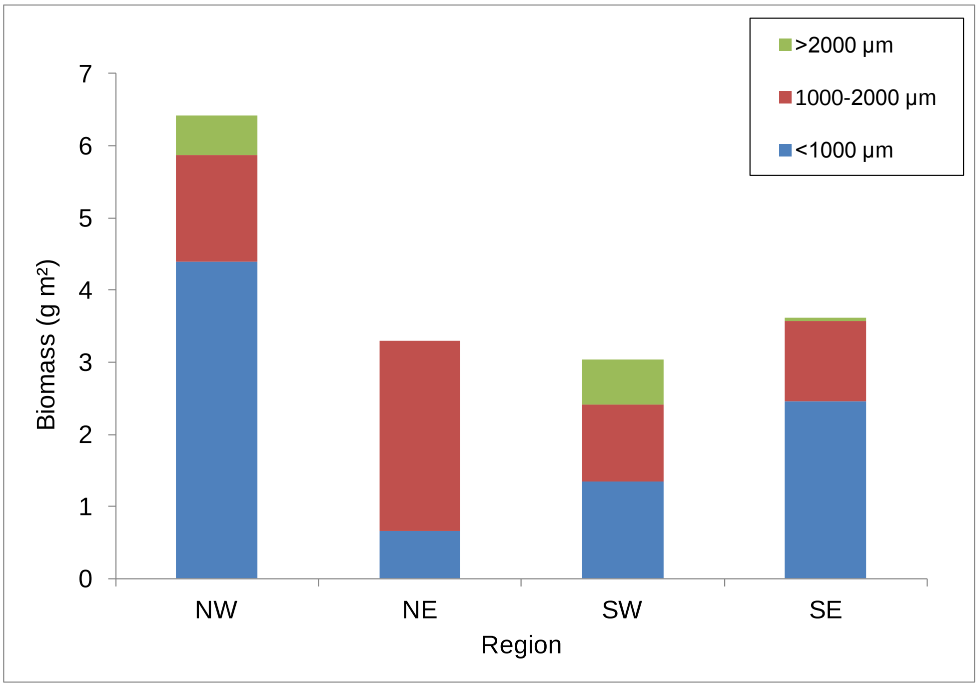


Figure 17. Plankton biomass (g m²) and size fraction (<1000 µm, 1000-2000 µm, >2000 µm) biomass within the sample from each region.

Marine mammal observations

Marine mammals were the only potential predator analysed in this study. They were observed in patches throughout the Norwegian Sea, but were not sighted along the scrutinized transects in this study (Figure 18). However, in the SE region, an individual sperm whale was sighted prior to the transect.

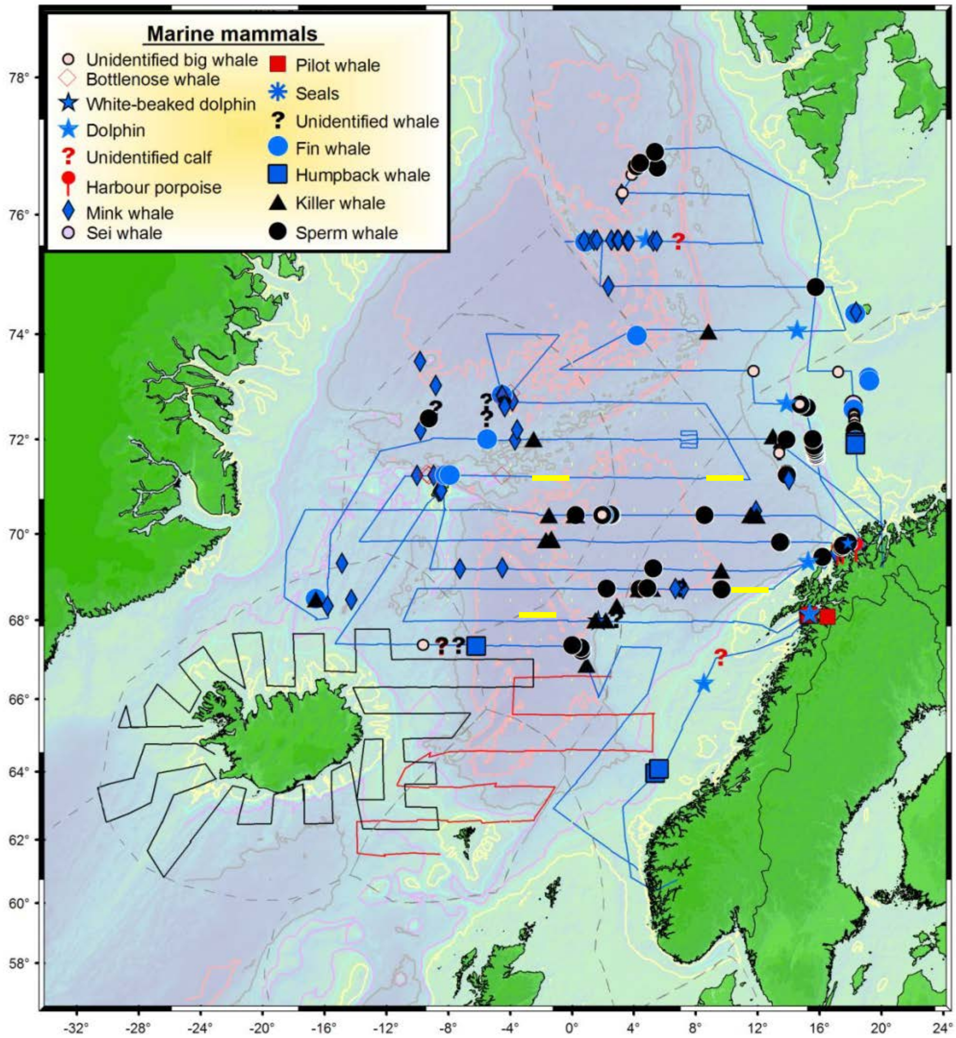


Figure 18. Marine mammals observed in the Norwegian Sea onboard M/V “Libas” and M/V “Brennholm” between stations in daylight hours, 15 July - 20 August 2010 (Nøttestad *et al.* 2010). The yellow lines indicate the location of the SONAR sampling transect.

Discussion

To the best of my knowledge, the schooling dynamics of NEA mackerel on the summer feeding migration has not been thoroughly analysed in relation to temperature, currents, and biological parameters prior to this study. Schools of mackerel flood the Norwegian Sea during the summer months for their annual feeding migration. All of the schools were detected within the upper 40 m of the water column, and most of the schools were swimming with the local prevailing current. The average mean school speed was the slowest in the NW, and significantly faster in the SW, which had a prevailing southerly current. Sea temperature, local plankton biomasses, density of conspecifics and predators are believed to affect school size, depth and swimming speed based on second-to-second individual trade-off decisions. Mackerel abundance and their schooling dynamics may therefore indicate the environmental state of the Norwegian Sea during the time of year when schooling pelagic fish are abundant.

Methodology

The survey was designed for different objectives, and was therefore not tailored specifically to the objectives of this study. The regions used in this study were chosen after the survey in an attempt to observe a gradient between north, south, east, and west based on inherent physical and biological differences. At least 50 mackerel schools were detected for a minimum of five seconds within each of the four selected study regions (NW, NE, SW, SE). The high mackerel stock in the Norwegian Sea during the summer allowed for many schools to be sampled during the survey period.

The LYBIN ray trace case study illustrated the influence of tilt angle on depth detections. Schools closer to the research vessel (e.g. < 85 m radius from the vessel) will be detected to have a shallower mean school depth, acquired from the series of school detections, than those further from the vessel. Axelsen and Misund (1997) pointed out that coupling SONAR and echosounder technology creates 3D observations of schooling dynamics for pelagic fish. Still, since mackerel are located in the upper blind zone of the echosounder close to the surface, SONAR may sometimes be the only reliable acoustic methodology to detect and track mackerel schools in summer. Individual school target tracking by multibeam SONAR will also provide more detections and thus greater accuracy in the measured school parameters (Kvamme *et al.* 2003).

The analysis of whether mackerel schools utilize STST highlighted the importance of calibrating the ADCP prior to the survey, as well as complications that can arise as a result of having to reprocess misaligned data. The magnitude of the currents was much more reasonable in the raw data than in the reprocessed data, which provided currents up to 4 m s^{-1}. However, the direction needed to be corrected by reprocessing the data. Thus, the raw data had to be combined with the reprocessed data to accommodate more reasonable representation of the local currents.

Horizontal and vertical mackerel distribution linked to temperature

NSS herring and NEA mackerel are two highly abundant pelagic fish species performing migrations throughout the Norwegian Sea. Mackerel were distributed from the southern edge of the Norwegian Sea to as far as 75° N in July - August 2010. The majority of mackerel schools at the end of July were distributed between 67° and 72° N, including farther East along the Norwegian coast and fjords, and far west into Icelandic and Jan Mayen waters. Mackerel made up the majority of the trawl catches in most areas except along the periphery of the Norwegian Sea and surrounding waters in the west (Iceland), northwest (Jan Mayen) and northernmost regions (Bear Island) where herring dominated.

The spatial overlap between mackerel and herring within the four selected regions in my study was limited. This coincided with the low overall overlap between the two species in the entire Norwegian Sea ecosystem in July - August 2010 (Nøttestad *et al.* 2010). Utne *et al.* (2012) determined that the vertical overlap between herring and mackerel is high, but horizontal overlap was limited during the summertime from 1995 to 2006. This is probably because herring migrate through the Norwegian Sea earlier than mackerel (Broms *et al.* 2012; Holst *et al.* 2004). A major factor influencing the spatial distribution of both herring and mackerel in summertime is the oceanic front between the cold Arctic water masses in the East Iceland Current and the warmer Atlantic water in the central Norwegian Sea, which are influenced by climate variation (Misund *et al.* 1997; Varpe *et al.* 2005). During part of the summer feeding migration, herring prefer to feed in polar front areas (Nøttestad *et al.* 2007), in contrast to mackerel (Nøttestad *et al.* 1999).

In July, when mackerel have their maximum geographical distribution and expansion in the Norwegian Sea, the herring has been feeding in this ecosystem for several months. In April, the highest concentrations of herring occupy the central and eastern areas of the Norwegian Sea. These large concentrations are replaced by mackerel later in July and August, and the older herring are now distributed primarily in the northernmost part of the Norwegian Sea, west of approximately 10° E, and north of 70° N (Broms *et al.* 2012). NSS herring distribution was found to correlate with the overwintering of *C. finmarchicus*. By the time mackerel have arrived to the Norwegian Sea, the herring have then moved farther north and west, past the 7° C isotherm and consumed the preferred stages (IV-VI) of *C. finmarchicus*, though not depleting the abundance (Melle *et al.* 2004). This west- and northward feeding migration of herring may also be influenced by fish condition (Dragesund *et al.* 1997; Nøttestad *et al.* 2004). These seasonal movements may allow mackerel to adapt and move into the Norwegian Sea in July, while both passively filter feeding and actively particulate feeding on available zooplankton concentrations.

In general, the schools occurred in the upper 40 m of the water column throughout day and night in the Norwegian Sea during my study period. NEA mackerel were distributed from 8 - 39 m depth with an average of 22 m depth. All of the schools were located above the given thermocline for each of the four regions, and occurred in waters of at least 6° C, with the majority of schools in waters between 7° - 11° C. Godø *et al.* (2004) examined aspects of schooling behaviour for mackerel during the summer feeding migration in the Norwegian Sea, but due to lack of data they were not able to substantiate the observed schooling dynamics with temperature. Therefore, this study contributes new knowledge related to physical preferences of mackerel schools. Prior to this study, 8° C was thought to be lower boundary of the preferred temperature range for NEA mackerel (Iversen 2004), but the present results indicate that this preference limit should actually be 7° C, as Castonguay *et al.* (1992) found for mackerel in the western Atlantic. In the NW, the variation in school depth, compared to the other regions, suggested that the depth distribution in this cold region was influenced by the shallower thermocline. In the warmer SE, the depth distribution of the schools was not strictly determined by temperature because the sea temperature was at least 7° C down to 160 m depth. Feeding conditions and light levels were probably the main driving forces behind the depth distribution in this region (see later).

Both the horizontal and vertical distribution of mackerel from acoustic and biological samples was found to be considerably influenced by their surrounding sea temperature. This suggests that mackerel distribution is constrained by low temperatures, both in the horizontal and vertical dimension. Temperature acts on pelagic fish as a proximate factor by affecting locomotor response, and ultimately determines the distribution (Nøttestad *et al.* 2004). Temperature preferences are main contributors in governing the large-scale distribution of planktivorous pelagic fish species (Langøy *et al.* 2012; Utne *et al.* 2012). Pelagic fish may generally move into waters slightly beyond their preferred temperature range, but ultimately temperature will set the distribution boundary (Kvamme *et al.* 2003). Temperature may therefore be used as a proxy for maximum geographical extent for NEA mackerel during the summer by following the 6° C isotherm in the horizontal and vertical dimensions. Fish respond to temperature effects by “behavioural enviroregulation,” which is when an animal adjusts its behaviour to regulate immediate environmental conditions. Mackerel utilize behavioural enviroregulation in response to changing temperature regimes both their horizontal and vertical distribution. Mackerel distribution was significantly positively correlated with temperature in accordance with an expected preference for warmer waters. Yet, mackerel are known to be able to adapt to high temperatures in its southern distribution range in more sub-tropical water masses (Uriarte and Lucio 2001) and to relatively low temperatures in the northern more Arctic waters (Nøttestad *et al.* 2013). Even though temperature often sets the physical extrinsic limit for distribution and behaviour, nonthermal factors such as photoperiod, currents, and biotic interactions may highlight the ecological importance of a temperature response (Reynolds 1977). Furthermore, nonthermal variables may act as additional proximate factors in response to temperature (Reynolds 1977).

Swimming speed and the effect of currents

The average swimming speed did not differ between the day and night in this study, which is consistent with Macy et al. (1998). Swimming speed of mackerel schools was on average 1.33 m s^{-1} with an average school speed of 1.44 m s^{-1} as a result of the prevailing currents. It could be argued that the effect of the current is relatively small, accounting for 10% of the school speed. In tank experiments, mackerel can maintain a swimming speed of 4.1 B.L. s^{-1} for at least 30 minutes at 11.7° C (Dickson et al. 2002; Wardle & He 1988); corresponding to approximately 1.44 m s^{-1} based on a 35 cm fish. School swimming speed found in this study for mackerel schools was predominantly between 0.72 and 1.79 m s^{-1} in all four regions. The mackerel schools in this study may therefore have been able to maintain their average swimming speed for prolonged periods during their feeding migration, particularly along the coastal regions as a result of warmer surrounding sea temperatures. Data accuracy of the school parameters increases with the number of pings, as schools with more than ten pings were more accurate than those with less than ten pings. Therefore, in future projects, reducing the vessel speed occasionally and/or remaining in one area, will allow schools to be tracked for longer durations, and thus, result in improved calculations of school speed and direction.

Similar results were found with NSS herring schools tracked with SONAR along the Norwegian coast (Kvamme et al. 2003).

NEA mackerel and other scombrids lack a swimbladder and must swim constantly at a speed of at least 0.4 B.L. s^{-1} to avoid sinking and maintain a constant depth (Wardle & He 1988), which is approximately 0.14 m s^{-1} based on a 35 cm long mackerel. The results coincide with earlier findings, and suggest that mackerel during summer in the Norwegian Sea maintain their movements above minimum swimming speed in order to remain in the upper most productive water masses and avoid sinking to deeper waters. The school speed was significantly higher in the SW compared to the NW and NE, which coincided with warmer sea temperatures. Decreased temperature can slow locomotor responses in fish and act on a fish through the central nervous system (Dickson et al. 2002). Fish are provided higher muscle fibre contraction in warmer temperature, as well as by a more direct action on the metabolism with slower metabolism in lower temperatures (Harden Jones 1968). Axelsen and Misund (1997) observed that NSS herring schools swam faster when the average sea temperature was higher, resembling the results on mackerel in this study. Other previous studies have also stated that metabolic rate and maximum sustainable swimming speed generally increase with temperature (Dickson et al. 2002).

The prevailing ocean currents in the NW, NE and SE regions of the Norwegian Sea were in a northern direction, whereas the current direction in the SW was predominantly to the south. Interestingly, the majority of mackerel schools were found to be swimming with the current, even in the SW. Schools rely on the prevailing currents during long-distance migrations to reduce energy expenditure via STST, in which schools swim with the prevailing current. Off the coast of North America, mackerel have previously been found to utilize the tidal cycle to reach their spawning grounds (Castonguay and Beaulieu 1993). The northward zooplankton production cycle forces pelagic planktivorous fish to follow the production cycle of zooplankton, and the concurrent prolonged day length increases the feeding period for visually feeding planktivorous fish (Nøttestad et al. 1999). Mackerel may take advantage of the currents accordingly to actively follow zooplankton prey in the summer migration to reach higher latitudes.

Since day length increases the farther north mackerel migrate, including midnight sun in the northernmost areas, mackerel as a visual predator would benefit energetically by migrating to and staying in areas where day length is longest and where plankton production is high simultaneously (Nøttestad et al. 1999). Larger fish were consistently caught in the north, supporting the length-based hypothesis for feeding migrations in pelagic fish proposed by Nøttestad et al. (1999) and later confirmed (Utne et al. 2012; Nøttestad et al. 2013). The larger mackerel are capable of swimming greater distances probably because they are more efficient feeders (Iversen 2004) and have greater tail propulsion (Videler 1991). Large fish are also better at foraging than small individuals because they have greater visual and swimming capabilities, and therefore may out-compete the smaller individuals in direct competition for food items (Hoare et al. 2000).

NEA mackerel in the SW were moving in a southern direction with the prevailing current along the cruise track. The SW data on both current and swimming direction may indicate a meso-scale oceanic eddy. The SW region was characterized by smaller fish, smaller school biomasses, and a predominantly southwards direction by mackerel. Oceanic meso-scale eddies are considered oases for marine life because they circulate nutrients (Godø et al. 2012). Thus, eddies can create patchy and highly clumped distributions of organisms (Parrish and Edelstein-Keshet 1999). This particular area may have had a relatively high amount of plankton being trapped inside an eddy. The closest plankton sampling station was prior to the SONAR transect, so concurrent plankton data were not available in this particular area. Nevertheless, such eddies can circulate available plankton for prolonged periods (Godø et al. 2012), and the best feeding strategy for pelagic fish may be to remain in an area as long as the feeding conditions are sufficient (Kvamme et al. 2003).

Food availability and feeding behaviour

The average plankton biomass throughout the Norwegian Sea was 4.71 g/m² during the survey period. Plankton concentrations varied between the four regions from 3.08 g/m² to 6.52 g/m²; the plankton abundance was nearly twice as high in the NW compared to in the SW. Mackerel in the north were swimming slower than in the south, indicating that swimming speed was related to local food abundance. Although there were not enough plankton samples to make substantial statistical analyses, these findings support Macy *et al.*'s (1998) tank experiments, which found that fish swam slower at high food concentrations and faster at low food concentrations.

The copepod *C. finmarchicus* is an important prey item for NEA mackerel (Iversen 2004). Earlier studies in the Norwegian Sea has suggested that *C. finmarchicus* is a valued prey species for mackerel during the summer months, although not the only one (Prokopchuk and Sentyabov 2006; Langøy *et al.* 2012). During summer, *C. finmarchicus* faces large fluctuations in both phytoplankton biomass and predator abundance (Dale and Kaartvedt 2000), and they normally begin to descend to deeper waters for overwintering by late July (Kaartvedt 2000). Planktivorous fish may affect the timing of spawning and descent and hence the number of generations per year (Kaartvedt 2000).

The plankton samples in this study were comprised of zooplankton of various size fractions. The small sized zooplankton dominated, followed by medium sized zooplankton. Smaller sized zooplankton (< 1000 μm) was the most abundant in the NW, but there were also some large zooplankton (> 2000 μ). The large percentage of small plankton in the NW suggests heavy selection by pelagic fish that had migrated through that area prior to sampling. Intense selection pressure on larger plankton species by planktivores will eliminate the large species, and the smaller species will predominate (Brooks and Dodson 1965). Still, mackerel are efficient at utilizing small planktonic prey. Langøy *et al.* (2006) found that small copepods (< 1000 μm) were numerous in the plankton samples throughout the Norwegian Sea, but were not dominant in mackerel stomach samples, suggesting that mackerel performed selective feeding.

School size, patchiness and competition

The mackerel schools in this study were generally small and estimated school biomass ranged from 200 kg to approximately 10000 kg in the four study regions. The trade-off between safety in numbers and feeding competition between co-specifics probably limit the school size of NEA mackerel during the active feeding period. Group foraging can increase the feeding rates of individuals whenever food is scarce and patchily distributed, since animals in groups find and consume food faster than lone individuals (Clark & Mangel 1986), and larger schools find food faster than smaller schools (Ward *et al.* 2011). Yet, feeding efficiency is decreased when a school is too large as a result of increased competition over the available food.

We can assume that the faster schools were denser than the slower schools, denser schools are more elongated, and slower schools are less polarized and more oblong in shape (Misund 1993; Pitcher and Parrish 1993; Himelrijk 2010). Group size and shape fluctuate as a function of resources, physiology, predominant activity, and sensing limitations (Parrish and Edelstein-Keshet 1999). Hunger and low predation pressure tends to loosen a strict school structure (Misund 1993; Mackinson *et al.* 1999), whereas high predation pressure increases the school size and density (Nøttestad *et al.* 2002). School size and structure is an obvious response to predation risk (e.g. Fréon *et al.* 1992).

Only an individual sperm whale was sighted near the beginning of the SE transect, indicating a low predation pressure from marine mammals in all of the four regions. Sperm whales do not normally constitute any immediate threat to pelagic schooling fish. Otherwise there were no sightings of marine mammals along or in the vicinity of any of the four transects. Many of the marine mammals mainly occurred in the central Norwegian Sea. A reduced amount of marine mammal predators over the years have been found in the Norwegian Sea (Nøttestad *et al.* 2013 submitted) and may have reduced the overall predation pressure on the pelagic fish stocks. Although the distribution of killer whales has been found to significantly overlap with mackerel in the Norwegian Sea (Nøttestad *et al.* 2013 submitted), the relatively small sized schools observed during the summer, indicates that the mackerel schools had low overall predation pressure and did not have to form larger schools to compromise individual feeding opportunities.

Meso-scale observations in this study revealed schools were patchy and swimming against the current. In the SW, the majority of the schools were small (less than 1350 kg on average) and the individuals within those schools were also the smallest of the four regions. The schools were more numerous in the SW, with nearly double the amount of schools along 10 km of transect compared to the other regions. Therefore, the SW had the shortest average nearest neighbour distance of the four transects. Low plankton abundance and lack of predators may have allowed for the schools to form small and loose schools in the SW, yet still remaining in proximity of a neighbouring school to join when necessary.

Diurnal behaviour

The NE region consisted of both a day and night segment 31 July - 1 August 2010 at approximately 71° N. This segment was the only suitable cruise track with "good data" in terms of multibeam SONAR data quality and pelagic trawl hauls with mackerel comprising the majority of the planktivorous fish species. Nearest neighbour distance did not differ between day and night, but schools were found to be smaller and deeper at night compared to during the day. Because of the depth range of the data, the statistical results illustrated that the schools were deeper at night than during the day; however, this difference was only by approximately four meters, which is relatively minor in terms of the possible depth range where the bottom depth exceeds 500 m. Furthermore, the following plankton station indicated greater plankton abundance farther east, so the mackerel observed during the night may have been foraging deeper in this area. Mackerel might not perform DVM during the summer;

rather, their vertical and horizontal distribution is based on prey abundance at these high latitudes with the prolonged daylight period. Approximately 20 - 24 hours of daylight at high latitudes in the Norwegian Sea should ensure more or less continuous visual feeding opportunities for the mackerel (Langøy *et al.* 2006).

Due to the midnight sun at high latitudes during spring and summer, the distinction between day and night is so reduced that the cues needed to initiate migrations could leave the copepods without a safe interval for feeding, thus eliminating the advantages of DVM (Dale and Kaartvedt 2000). The visual range of planktivores is highly sensitive to illumination (Dale and Kaartvedt 2000), and the midnight sun is a benefit for mackerel, allowing extended feeding periods at higher latitudes for these effective visual predators (Nøttestad *et al.* 1999). According to Dale and Kaartvedt (2000), the older stages of *C. finmarchicus*, preferred by mackerel, underwent DVM during the summer in the Norwegian Sea; however, this behaviour was scarce at high latitudes in oceanic waters. Still, their data displayed flexibility in copepod DVM behaviour depending on different environmental conditions.

Mackerel and herring possess very similar characteristics and the potential to occupy the same niche (Skjoldal *et al.* 2004; Dommasnes *et al.* 2004). Herring conduct DVM with varying intensity throughout the year. This is also the case for mackerel, but to a lesser extent during the summer. It can be speculated that mackerel do not have the need to perform DVM due to the midnight sun and limited predation pressure. They thrive in the upper layers of the water column where light improves their abilities to constantly feed on large copepods. Pitcher (1993) recognized that within the scombrids, several species do not display well-defined activity periods. Additional diurnal studies of mackerel behaviour should be performed during the summer to better elucidate the diel vertical behaviour and depth preferences of actively feeding mackerel schools.

Ecological context

The NW displayed a shallower thermocline, and thus cooler sub-surface sea temperatures due to the influence of the Arctic front. The thermocline depth limited the maximum depth of the schools to approximately 28 m. These cooler waters could create an optimal environment for higher biomass of larger zooplankton from input of nutrient-rich Arctic waters. Larger mackerel formed larger schools than compared to in the other regions and swam north against the current to feed in this richer and more productive region. The relatively high food abundance should reduce local competition and allow the schools to be larger than in the southern areas with lower prey abundance. The lower range of swimming speeds in the NW could be due to a combination of the lower temperature and higher zooplankton abundance. The NE was characterized by even slightly larger fish than those in the NW, and slightly smaller average school biomass, probably in connection with lower local zooplankton biomass compared to in the NW. The deeper thermocline depth may have allowed fish to forage at slightly deeper depths where zooplankton abundance was possibly greater than in slightly shallower depths.

Mackerel occurred significantly deeper in the SW than the other regions, although the depth where temperature reached 7° C was the same as in the NE. The SW schools swam faster and in much smaller aggregations, which contained the smallest individuals of the four regions. The zooplankton biomass was the lowest in this region. In general, the mackerel schools in the south swam faster than those in the north probably due to sub-optimal feeding conditions and warmer sub-surface sea temperature. Mackerel in the SE swam in various directions in search of more food patches, where as the schools in the SW swam south within a meso-scale eddy that possibly contained rich concentrations of zooplankton.

The spatial distribution of mackerel in each region probably reflected dynamic trade-offs between available food in combination with potential predator threat and experienced temperature regime. Lack of potential marine mammal predators in all four regions during the survey period may have resulted in smaller and looser schools adapted to limited food. In the north, mackerel schools were large; a common response to predation pressure. However, food abundance was also high in the NW so it was probably not necessary to dissolve into smaller schools. In particular, in the SW the schools were relatively close together and in small aggregations that could be prepared to join a neighbouring school in response to predator attacks. Even without predation pressure in these four regions, the schools in the north probably traded off safety over maximizing feeding as a result of close to record low levels of zooplankton abundances in the Norwegian Sea in 2010 (Huse *et al.* 2012).

Conclusions

Given that NEA mackerel is one of the most important ecological and economical fish species in the Atlantic Ocean, there is notably little knowledge available regarding schooling behaviour and ecology of this species. This study has produced new data on parameters such as school size, depth, swimming speed, direction, and clustering in relation to prevailing current systems. The observed schooling dynamics have shed new light on the ecological situation of mackerel schools during their extensive feeding migrations at high latitudes.

Large stocks of commercially important pelagic fish conduct extensive feeding migrations through the Norwegian Sea in preparation for the oncoming overwintering period. Improved knowledge of the schooling dynamics of NEA mackerel will enable scientists to predict their patterns for better understanding their ecological role in marine ecosystems. Acoustic observations using modern multibeam SONARs coupled with biological sampling at different trophic levels and oceanographic measurements, provides new genuine insight into the highly dynamic pelagic ecosystem in the Norwegian Sea. This thesis illustrated the gain by systematic use of fisheries SONAR in ecosystem surveys, as well as the drawbacks that can improve data collection, efficiency, and accuracy. The horizontal and vertical distributions, swimming direction and speed, and diurnal behaviours of the summer feeding migration exposed in this study provide a basis for more efficient SONAR detection and quantification of swept area for abundance estimation of NEA mackerel by standardized pelagic trawling.

In future projects one or more of the following tasks should be considered: 1) reduce vessel speed to perform target tracking of mackerel schools lasting at least 60 seconds for a more accurate estimation of swimming speed and direction; 2) choose a smaller dedicated study area and remain in one area for prolonged periods to design experimental field studies, including hypothesis driven behavioural and ecological process studies on diurnal time scales; 3) include data from the southern distribution of mackerel in the North Sea and west of the British Isles in summer in direct comparison with concurrent data from the Norwegian Sea to evaluate regional differences between two marine ecosystems; and 4) calibrate the ADCP prior to the survey to have more accurate direction and magnitude data for analysis of STST.

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Appendices

Appendix 1. Function developed in R to determine the altitude of the sun during the summer at high latitudes where daylight hours are prolonged.

```
alt.of.sun <- function(min=x$min, hour=x$hour, day=x$day,
month=x$month,
                lat=x$lat, lon=x$lon, x=NULL)
{
    # altitude of sun
    UTC <- hour+min/60
    CET <- (UTC + 1) %% 24
    dayadd <- cumsum(c(0,31,28,31,30,31,30,31,31,30,31,30,31))
    cumday <- day + dayadd[month]
    K1 <- (lon - 15 - 0.4083 * sin(0.0172 * (cumday-80))
                               - 1.7958 * cos(0.0172 *
(cumday-80))
                               + 2.4875 * sin(0.0344 *
(cumday-80)))
    SST <- ((CET*15) + K1) / (180/pi)
    dkl <- asin(0.3979 * sin((0.0172 * (cumday - 80))
             + 0.03346 * (sin(0.0172 * cumday) - 0.98112)))
    Brq <- lat/(180/pi)
    sinush <- (sin(dkl)*sin(Brq)) -
(cos(dkl)*cos(Brq)*cos(SST))
    alt.of.sun <- asin(sinush) * (180/pi)

    # time when altitude of sun = asun.0
    asun.0 <- 0
    K2 <- (sin(dkl)*sin(Brq) - sin(asun.0/(180/pi))) /
(cos(dkl)*cos(Brq))
    K2[K2 < (-1)] <- -1       # polar night
    K2[K2 > ( 1)] <-  1         # midnight sun
    SST0 <- acos(K2)
    CET0 <- (SST0 * (180/pi) - K1) / 15
    UTC0 <- (CET0 - 1) + 24*(CET0 < 1)
    sun.rise <- UTC0%%24
    list(alt.of.sun=alt.of.sun, sun.rise=sun.rise)
}
```

Appendix 2. SH90 SONAR pre-processing settings used per region for automatic detection of schools.

Region	NW	NE	SW	SE
Tilt (degrees)	-4 to -6°	-6°	-4°	-6°
Sampling radius (m)	85 - 300	85 - 300	85 - 300	85 - 300
Alpha	0.7	0.1	0.7	0.5
Alpha radius (number of pixels used)	1	2	2	1
Time median radius (number of pings on either side)	2	3	2	2
Threshold	0.4	0.3	0.8	0.3
Min max Sv	101.5	100.5	100.5	101.3
Min area (m)	10	10	10	10
Max area (m)	20000	20000	20000	20000
Max aspect ratio	16	16	16	16

Appendix 3. R syntax using per ping data to calculate a more accurate mean fish school speed and direction.

```
xps$Speed<-as.numeric(as.character(xps$Speed)) #per school to compare
xps$Heading<-as.numeric(as.character(xps$Heading)) #per school to
compare

# Reshape time to R format
dt2<- paste(x$Date, x$Time)
dt3<-strptime(dt2, "%Y-%m-%d %H:%M:%OS")
dt3<-format(dt3, format = "%Y-%m-%d %H:%M:%OS2")
options(digits.secs = 2)
x$dt4 <- as.POSIXct(dt3,format="%Y-%m-%d %H:%M:%OS",origin="1960-01-
01", tz="GMT")

# Define a function that converts compass headings (bearings,
azimuths) into geometric angles for trigonometry.
# Examples:  For a heading = 0 degrees, vector points due north, and
angle = 90 deg.
# For a heading = 90 degrees, vector points east, and angle = 0 deg.

convert.heading.angle <- function(heading) {
num.heading <- length(heading)
angles <- rep(NA, num.heading)
for(i in 1:num.heading) {
    angles[i] <-
      ifelse((heading[i] >=0 && heading[i] <= 90), 90 - heading[i],
```

```
            ifelse((heading[i] >=90 && heading[i] <= 180), 360 -
(heading[i] - 90),
                    ifelse((heading[i] >=180 && heading[i] <= 270),
180
+ (270 - heading[i]), 90 + (360 - heading[i]))
                   )
            )
  }
return(angles)
}  # end of convert.heading.angle()

#create variables for loop
pId<-unique(x$Id)
lat0<-vector(length=length(unique(x$Id)))
lon0<-vector(length=length(unique(x$Id)))
posMet<-vector(length=length(unique(x$Id)))
deltaSec<-vector(length=length(unique(x$Id)))
res<-data.frame()

#Calculations made from mean position (lat-long)
library(SoDA)
for(i in 1:length(unique(x$Id))){
Subindex<-(pId[i])
lat0<- mean(x$Center.lat[x$Id==Subindex])
lon0<- mean(x$Center.lon[x$Id==Subindex])
posMet<-geoXY(x$Center.lat[x$Id==Subindex],x$Center.lon
[x$Id==Subindex],lat0,lon0,unit=1) #distance (m) for each detection
to mean position

deltaSec <- as.numeric(x$dt4[x$Id==Subindex]) -
as.numeric(min(x$dt4[x$Id==Subindex]))#delta in time (sec)

fit_X<-lm(posMet[,1]~deltaSec) #linear curve fitting  of distance in
lat and long by time
fit_Y<-lm(posMet[,2]~deltaSec)

a<-fit_X$coefficients[[2]]    #regression slopes
o<-fit_Y$coefficients[[2]]
Vel<-sqrt(a^2+o^2)             #velocity from vectors
Theta<-atan2(o,a)*(180/pi)      #Theta angle in degrees
Bea<-convert.heading.angle (ifelse(Theta<0,Theta+360,Theta)) #Use
function from Heading to Bearing
res<-rbind(res,c(Subindex, Vel, Bea))#All together in one file
}
colnames(res)<-c("Id2","Vel","Bea")
```

An insight concerning the blue whiting (*Micromesistius poutassou*) spawning at IXa

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1. Introduction

The blue whiting fishery is the largest fishery in the Northeast Atlantic (BjØrndal, 2009).
In this entirely region the ICES Blue Whiting Assessment Working Group (BWAWG) considered until 1993 two main stock components, a northern and a southern, with a southern boundary at Porcupine bank (ICES, 1994).

Since 1993, ICES BWAWG proposed that this species should be assessed as a single stock for the Northeast Atlantic distribution area. Despite, the results of a study based on isozyme electrophoresis (Mork and Giæver, 1993). These Norwegian scientists used for this purpose samples from the Barents Sea in the north to the inner Mediterranean (Greece) waters in the southeast. However, no samples off the Portuguese coast were used. Lower genetic heterogeneity was observed between samples from the spawning areas west of the British Isles. In the inner Mediterranean blue whiting were genetically separated, indicating a genetic substructure on a west-east axis from north of the British Isles. Also, differences found in the gene frequencies of the blue whiting from the Norway and the Barents Sea, indicated significant signs of being a reproductively isolated stock.

BWAG justified the single stock decision based on the fact that whether there exist one, two or more populations in this area, their geographical distribution is not clear and could change over time. Referring that Mork and Giæver study (1993) gave no indication of the genetic substructure among blue whiting from the west of the British Isles to Gibraltar. Besides, the assumption that the gene flows between the main stocks, are too high to get a significant sustainable difference (ICES, 1994). This single stock definition was further adhered by the ACFM (ICES's Advisory Committee on Fishery Management) and NEAFC (North East Atlantic Fisheries Commission).

Besides the work of Mork and Giæver (1993), several other studies have been shown that the actual single stock which is extended through the Norwegian Sea down to Portugal is in fact composed by two main populations (e.g. Pawson et al., 1978; Bussmann, 1984; Zilanov, 1984; Karasev, 1989; Monstad, 1990; Isaev and Seliverstov, 1991; Mork and Giaever, 1995; Skogen et al. 1997; Giæver and Stein, 1998; Brophy and King, 2007; Ryan et al., 2005; Was et al., 2008). The focuses of those studies as well as their foremost conclusions are in Table 1.

In 2011, based in a review of those studies the Scientific Technical and Economic Committee of the European Commission (STECF) concluded that there are "northern" and "southern" stock that, once technically feasible, should be treated as separate stocks for assessment and management. STECF, defined the southern boundary for the "northern" stock at 53.5ºN and a northern boundary for the "southern" stock at 52.0ºN. The northern boundary for the "southern" stock should extend from the west coast of Ireland to15ºW. The area north of 52.0ºN to 53.5ºN east of 15ºW was considered a "mixing area" and in a two stock management system, must be managed to guarantee that catches from this area do not compromise the management objectives for either the "northern" or the "southern" stock. In order to achieve the separation of stocks, STECF recommended ICES to make their own assessment of the "northern" and "southern" stocks, to ensure that information found is consistent with STECF data.

The stock was earmarked for a benchmark assessment, apart from some technicalities concerning the assessment, there was also been discussed the issue of whether or not blue whiting should be assessed as a combined stock at all. The benchmark occurred in the beginning of 2012 (ICES, 2012). The working group concluded that there is no scientific evidence in support of multiple stocks with distinct spawning locations or timings. Standing the blue whiting as a single stock whose large-scale spatial spread varies as a function of hydrographic conditions and total abundance, commonly described with an abundance-occupancy relationship (ICES, 2012).

The aim of this study is to provide an insight concerning blue whiting spawning at ICES Division IXa, which could be useful in the discussion of population units for this species. In order to achieve that purpose, the data collected, since the beginning of the 90's, for blue whiting off the Portuguese coast is reviewed.

2. Material and Methods

2.1 Data

Data were obtained from:
i) samples collected by bottom trawl during surveys carried out along the Portuguese coast, performed between 1990 and 2010.
ii) samples collected in a monthly regular basis (PNAB-DCF), since 1998.

The total length (cm), total weight (g), sex, and maturity stage of all sampled fish were recorded. From the surveys, also latitude and longitude of places of capture were available.

2.2 Maturity Stage Scale Key

From 1990 until 1998:

- a 7th scale maturity stage key was applied to the maturity classification of blue whiting gonads. The staging of gonads were made according to their main characteristics into the following stages: 1 – immature; 2 – maturing/recovery; 3 + 4 - development; 5 + 6 – spawning; 7 – post-spawning/resting. This maturity scale was validated by the means of histology by Cunha (1992).

Since 1998:

- A 5th scale maturity stage key was applied, with stage 1: immature/resting; 2 – development; 3+4 – spawning; 5 – post-spawning. The histological validation of this scale was performed by Amorim (2000).

3. Results

3.1 Length at 1st maturity

The analysis of the maturity stages by length, in the surveys collected data (i), shown the length of the first maturity by sex (Figure 1). Thus, the length of first maturity is 17cm for males, 19 cm for females and for sex-combined data.

3.2 Area of spawning for the IXa

The distribution of females in pre-spawning and spawning is shown in Figure 2. The figure shows the presence of females in pre-spawning stage spread along the all IXa area for the two periods of surveys (90's and 2000-2010). Although the presence of females identified in spawning stage was smaller than in pre-spawning stage, the area that they occupied is the same.

3.3 Spawning season

The maturity stages by month, was analysed in order to describe the spawning season (Figure 3, 4 and Table 2). The observation of figure 3 and table 2, revealed that the number of females at pre-spawning and spawning stages is higher between January and March, and from April decreases. Although, the surveys realized from January to March were reduced, figure 4 shows the pre-spawning and spawning females spread off the coast of Portugal.

Conclusions

The length of first maturity obtained in the current review, were similar to the one reached by Vasconcelos (1982), for females and males. Also, for sex-combined data the length is equal to the value published by Silva et al. (1996).

The occurrence of spawning along the coast of Portugal is in accordance with the results of previous works (Kloppmann et al., 1996; Silva et al., 1996; Standal, 2006). Confirming that the main spawning season stems between January and March as described in other studies (Cunha, 1992; Amorim, 2000). Schmidt (1909 *in* Raitt, 1968) also refers the possibility of a spawning off the coast of Portugal, in February.

This study indicates that for the IXa the spawning area do not change between years and at this point is well known.

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Figures

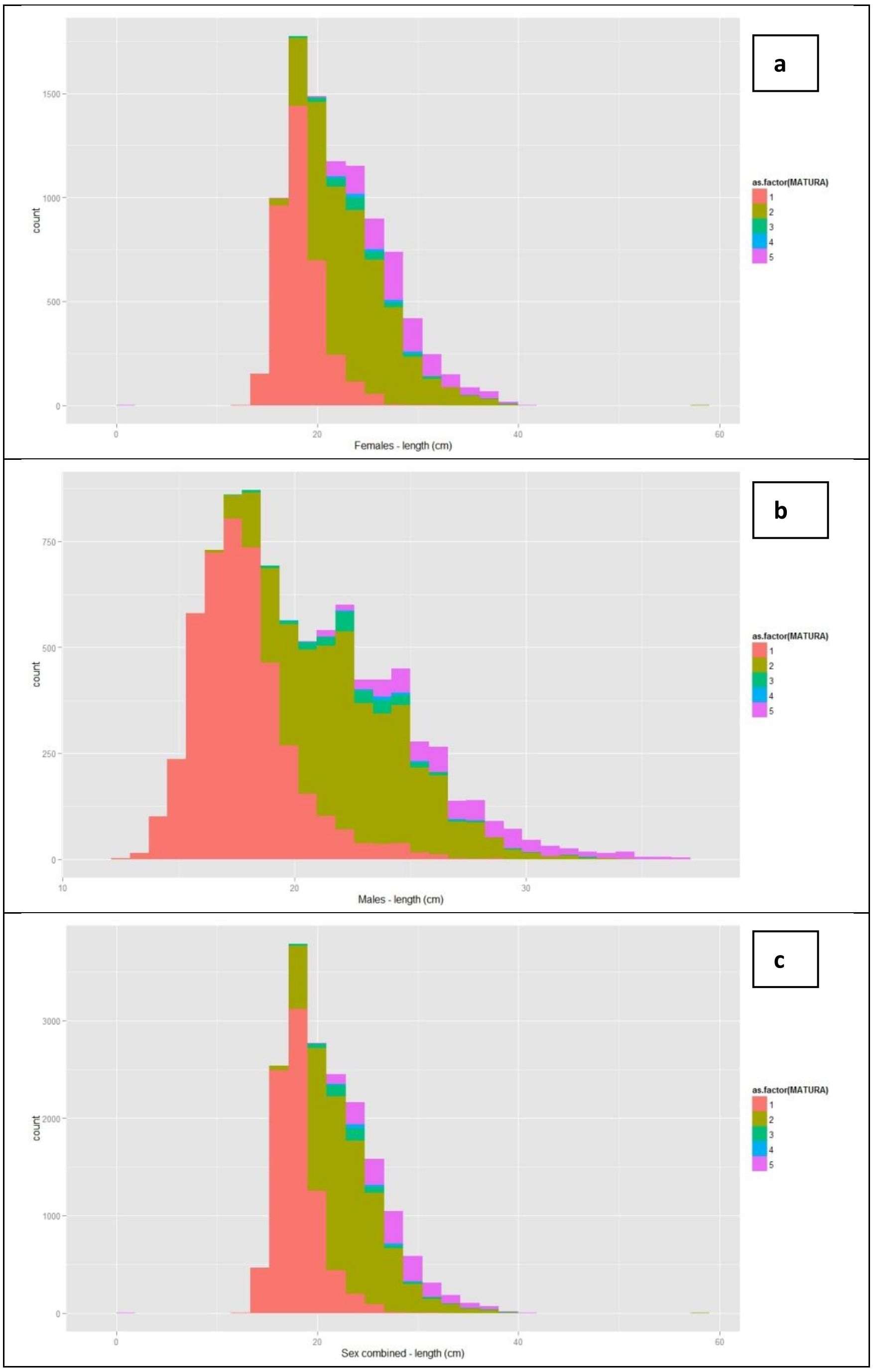

Figure 1 – Maturity stages (1 – Immature; 2 – Development; 3 – Pre-spawning; 4 – Spawning; 5 – Post-spawning) by length for: **a)** females; **b)** males; **c)** sex-combined.

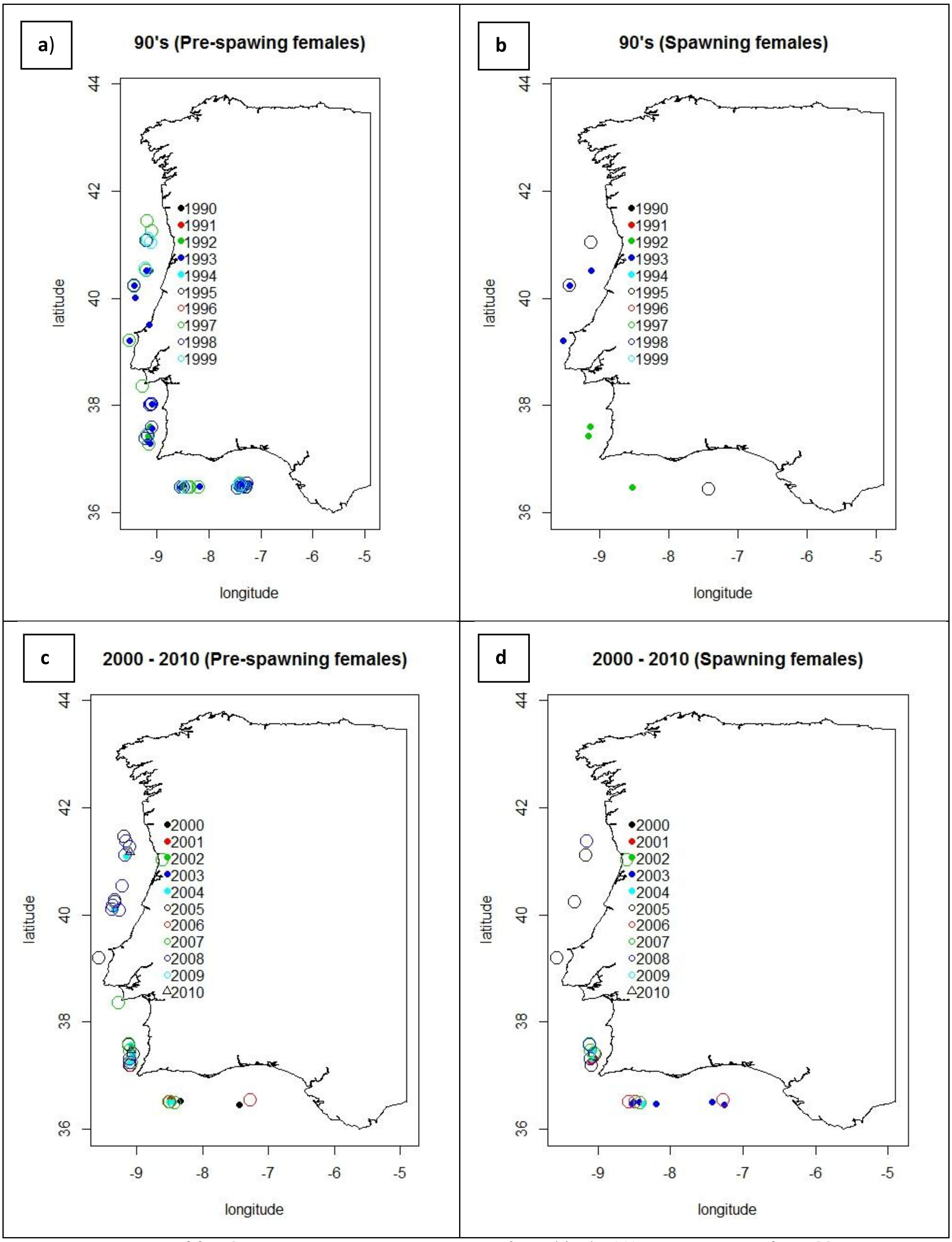

Figure 2 – Presence of females in pre-spawning (**a** – surveys performed in the 90's; **c** – surveys performed between 2000-2010) and at spawning (**b** – surveys performed in the 90's; **d** – surveys performed between 2000-2010) stages along the IXa.

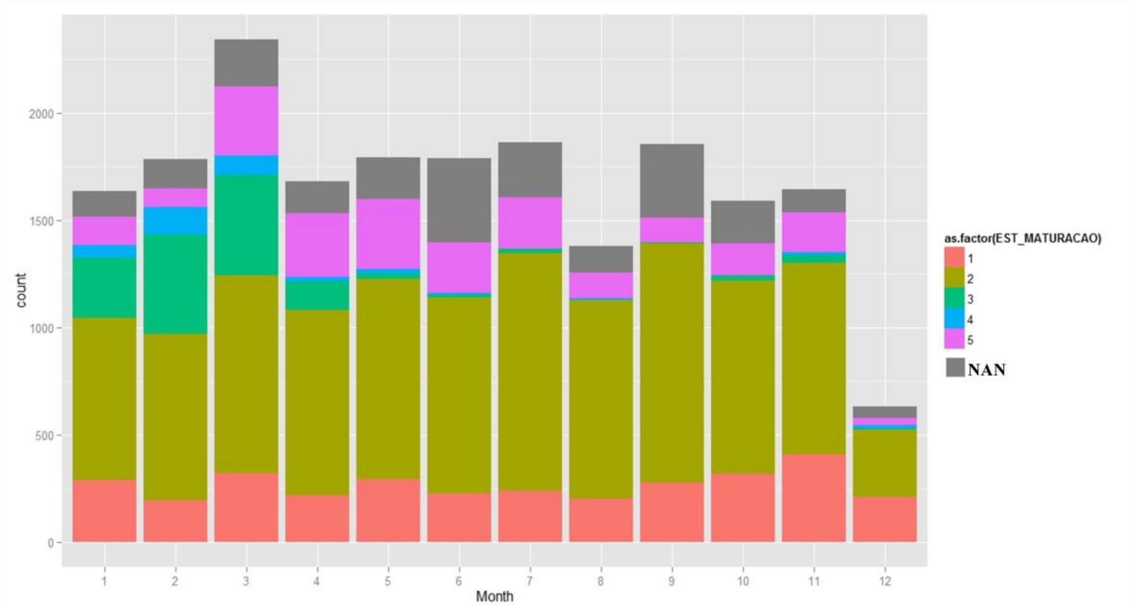

Figure 3 – The number of females by maturity stage (with 4 as pre-spawning and 5 as spawning) and by month sampled under PNAB-DCF.

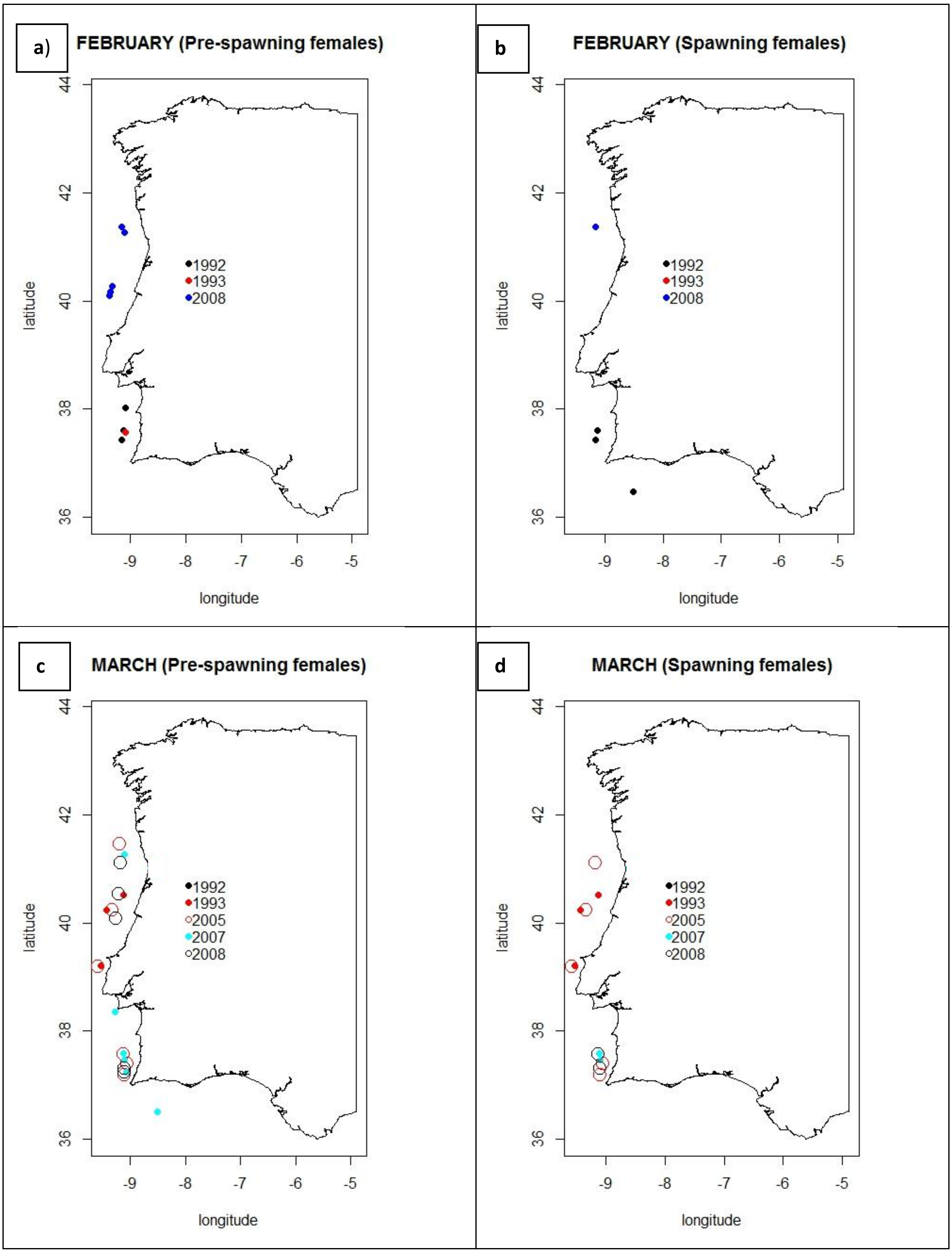

Figure 4 - Presence of females in pre-spawning (**a** – February; **c** – March) and at spawning stages (**b**- February; **d** - March) along the IXa.

Table 1 – Synthesis of the main studies shown focused on the population units for blue whiting along the Northeast Atlantic.

Reference	Conclusions
Pawson et al., 1978	The difference in otoliths structure between fish taken in north and south of the area under consideration may indicate that blue whiting from Biscay do not recruit to the main spawning populations in the Rockall Channel.
Bussmann, 1984	Based on frequencies of certain eye lense proteins in electrophoretic analyses, the results gave support to the hypothesis that separate stocks exist in the Norwegian Sea, Icelandic waters, west of British Isles and in the waters west of Ireland.
Zilanov, 1984	Suggests 4 stocks: 1) the Mediterranean, 2) west Atlantic; 3) Bay of Biscay; 4) the Hebrides-Norwegian stock.
Karasev, 1989	Focused on comparison of parasite types and infection rates suggests 3 stocks: 1) Spitzbergen, Barents Sea and Iceland; 2) Norwegian Sea, Faroes and Hebrides; 3) Porcupine Bank, Celtic Sea, Bay of Biscay and Shetland.
Monstad, 1990	Based on the blue whiting growth pattern, indicated that the growth in Hebrides area as quite similar to that in the Norwegian sea, which differed slightly from the growth in the Porcupine bank area. As a result of the influence of blue whiting from other areas which do not take part in the migration back to the Norwegian Sea.
Isaev and Seliverstov, 1991	Based on morphometrics and meristic characters suggests 5 stocks: 1) Mediterranean; 2) west Atlantic; 3) Bay of Biscay; 4) Porcupine; 5) Hebridean stock.
Mork and Giæver, 1995	Based on genetically examination of loci for the investigation, found genetically isolated populations in the Barents sea and in the Mediterranean
Skogen et al. 1997	Based on the modelled drift pattern of the larvae a separation line north of Porcupine Bank has been found. The line shows a large interannual variability indicating a mix between the two stocks.
Giæver and Stein, 1998	The genetic population structure of blue whiting throughout its east Atlantic distribution range was explored using polymorphisms at the tissue enzyme loci IDHP-2* and PGM-1*. The study included from 65 locations in the east Atlantic and the Mediterranean. Several separate reproductive units were indicated at the fringes of the distribution range, i.e. in the Barents Sea, and in one Norwegian fjord (Romsdalsfjord).
Ryan et al., 2005	Based on one minisatellite and five micro-satellite loci, analysed 11 samples of blue whiting from the Barents Sea, the Northeast Atlantic, and Mediterranean Sea. Their results indicated genetically differentiated populations at the latitudinal extremes of the range (Barents Sea and Mediterranean).
Brophy and King, 2007	Based on larval otholits increments in adult blue whiting shown that blue whiting spawning aggregations west of Ireland and Scotland do not form a randomly mixing unit, and that fish from feeding areas throughout the distribution do not contribute equally to spawning assemblages in the north and south of the spawning grounds. Concluded that blue whiting in the main spawning area do not form a randomly mixing unit.
Was et al., 2008	Based on landscape genetics approach, which combines spatial and genetic information, to detect barriers to gene flow. Four zones of lowered gene flow were identified, generally in concordance with hydrographic patterns, fish spawning behaviour, and the simulated transport of larvae in the NE Atlantic Ocean.

Table 2 – The number of females (%) sampled by maturity stage and by month, since 1998 (PNAB-DCF data).

	JAN	FEB	MAR	AP	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	18.9	11.6	15.1	14.2	18.3	16.2	14.9	16.0	18.0	22.7	26.6	35.9
2	49.9	47.2	43.4	56.3	58.5	65.3	68.8	73.8	73.9	64.8	58.0	54.8
3	18.5	28.0	21.9	8.7	1.5	1.0	1.4	0.0	0.2	1.9	2.5	0.7
4	3.9	7.9	4.3	1.3	1.4	0.4	0.0	0.5	0.0	0.0	0.8	3.1
5	8.8	5.2	15.3	19.5	20.3	17.0	14.9	9.7	7.9	10.6	12.0	5.5

Revising the maturity ogive for blue whiting

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Introduction

This document presents a first attempt to revise the maturity ogive for blue whiting, hopefully paving the way to inter-sessional work to revise the ogive for WGWIDE 2014. The current maturity ogive for blue whiting originates from 1994. The stock annex states the following:

> "Maturity at age used in the assessment was obtained by combining maturity ogives from the southern and northern areas, weighted by catch in numbers at age (ICES, 1995). These values have been used since 1994. Although the values of maturity at age may be too low, sufficient information for estimating new ogives is not available." (ICES 2012, p. 842)

This leaves open when and how the ogives for the southern and northern areas were derived in the first place, so it is rather difficult to make any judgements regarding how good (or bad) the ogives were 20 years ago or are now[1].

Errors in maturity-at-age are directly reflected in estimates of spawning stock biomass based on stock numbers and weight, and thereby it is important to try to understand how much bias and error may be entering the SSB estimate this way.

When the ogive for the northern stock component was estimated, there were two surveys covering larger parts of the stock: the Norwegian and Russian spawning stock surveys (March–April), and the Norwegian pelagic survey in the Norwegian Sea in July–August. The first survey represents almost only spawning fish, whereas the latter survey represents both immature and mature fish. Because the surveys are far apart in time, mature fish have ample time to move from one survey area to another, and the "same" fish could be observed in both surveys. One does not want to count the same fish twice, so it was difficult to combine data from these surveys.

However, the situation has changed. The spawning stock survey has developed into an international, coordinated survey (starting 2004). The survey in the Norwegian Sea in July–August became supplemented by another survey conducted in late spring, gradually becoming a coordinated survey with broad international participation (from about 1997, and further improving over time) and eventually replacing the old survey in July–August (discontinued in 2001). Thus, since about 2004, there has been coordinated, international survey coverage of the stock at both the spawning and feeding areas. The surveys are now only 1–2 months apart, reducing (but not totally eradicating) the problem of counting the same fish twice. This gives a much better basis for estimating maturity-at-age by combining survey data from spawning and feeding areas.

Methods

Data from 2004 to 2012 corresponding to the spawning stock survey in March–April and the pelagic ecosystem survey in May–June were extracted from the database of the Institute of Marine Research.

[1] I do not have the reports, but I seem to remember that the northern ogive was derived in early 1980's.

Thus only data collected by Norwegian vessels (either research vessels or chartered fishing vessels) were used. Estimated numbers-at-age corresponding to the aforementioned surveys were extracted from the 2012 assessment report (ICES 2012, Tables 8.3.5.1.1 and 8.3.5.2.1). Numbers-at-age for the pelagic ecosystem survey before 2012 were divided by 3.1 to account for the change in the target strength (Pedersen et al. 2011). A weighting factor for each individual observation was calculated as $w_{a,y,s} = N_{a,y,s}^{estimated} / N_{a,y,s}^{sampled}$ where the numerator is numbers per age per year per survey in the acoustic survey estimate and denominator is the total sampled numbers per age per year per survey. Individuals in macroscopic maturity stage 1 ("immature", coded as 0) were considered immature and all above (stages 2–7, coded as 1) mature (cf. Mjanger et al. 2010). Maturity-at-age can then be calculated as a mean maturity-at-age, weighted by the factor defined above.

Results

The ogive derived using the Norwegian survey data combined with estimated numbers-at-age suggests that the current ogive underestimates maturity by about 10–20 per cent points in age groups 2 to 7 years (Figure 1, Table 1). Recalculating SSB using the estimated stock numbers-at-age and weights-at-age from the 2012 assessment shows, as expected, that SSB is revised upwards. Looking at the absolute estimates gives an impression that the revision amounts to a mere re-scaling. However, a closer look on the results shows that the upward revision has fluctuated between 5% and 21% (assuming that the new ogive is representative for the early years, which can of course be questioned). The bias is largest when the spawning stock is dominated by young fish.

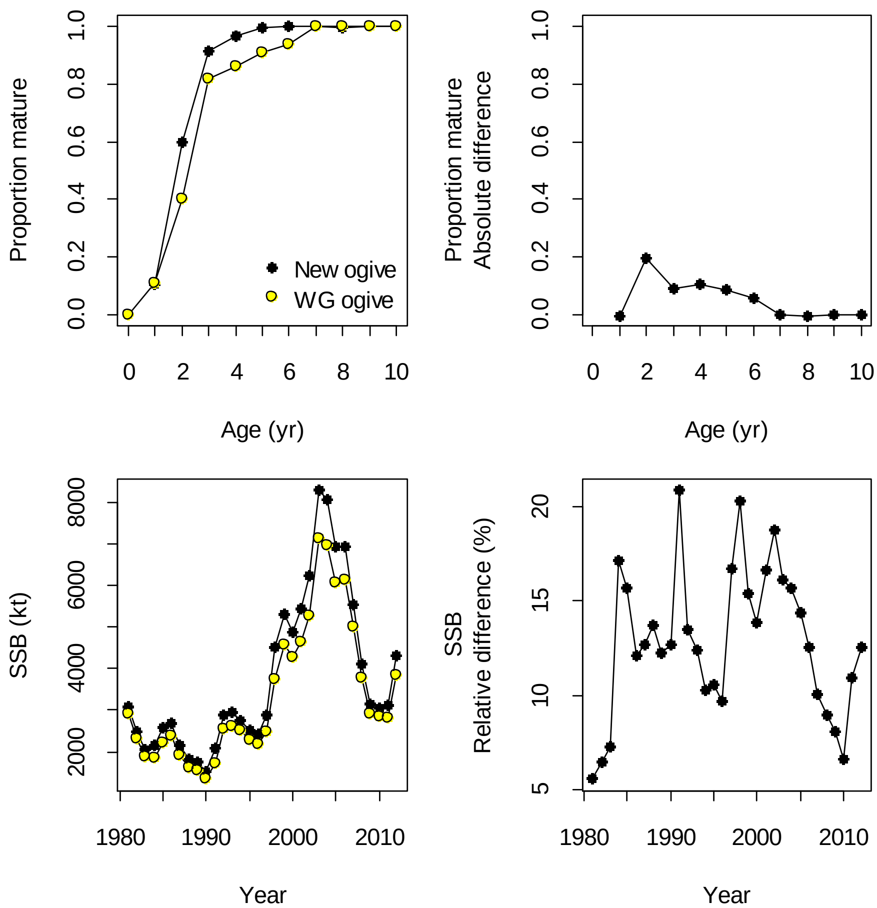

Figure 1. The provisional revised maturity ogive and its consequence for SSB.

Table 1. The current maturity ogive used in WGWIDE and the provisional revised maturity ogive.

Age	0	1	2	3	4	5	6	7	8	9	10
WG ogive	0	0.11	0.40	0.82	0.86	0.91	0.94	1.00	1.00	1.00	1.00
New ogive	0	0.10	0.60	0.91	0.97	1.00	1.00	1.00	1.00	1.00	1.00

Concluding remarks

Some of the hidden assumptions above are:

- Both surveys have the same relative observability. This is not true (if not for any other reason) because the estimate in Table 8.3.5.2.1 is for the “standard survey area”, so numbers-at-age are underestimated. This probably leads to overestimation of maturity-at-age.
- The same fish are not observed twice. This is probably not true either because some spawning fish will have moved to the area surveyed in May by that time. This probably leads to overestimation of maturity-at-age.
- Years receive relative weight that is proportional to stock numbers. Giving equal weight to each years is easily done but unlikely to have much effect.
- Norwegian data are representative. Hard to judge but easy to test.

The considerations above suggest that the provisional ogive represents the worst case—that the “true” ogive might lie somewhere between the old and new ogive.

The results here suggest that there is a significant downward bias in current SSB estimates. Assessments are relatively immune to a constant bias, but because the maturity ogive seems to be most biased for age 2 years, there is an error that varies from year to year, as long as incoming year classes differ in strength. I recommend estimating a new maturity ogive using all available data (i.e., also other countries than Norway), with appropriate checks for sensitivity of the estimate to data sources and structural assumptions.

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Pedersen, G., Godø, O. R., Ona, E., and Macaulay, G. J. 2011. A revised target strength–length estimate for blue whiting (*Micromesistius poutassou*): implications for biomass estimates. ICES Journal of Marine Science, 68: 2222 –2228.

2013 Mackerel and Horse Mackerel Egg Survey

Preliminary Results

by

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Introduction

The mackerel and horse mackerel egg survey is an ICES-coordinated international study in the north east Atlantic conducted during the first half of 2013. This study is a combined plankton and fishery investigation formed by a series of individual surveys which have taken place triennially since the late 1970s and is coordinated by the ICES Working Group on Mackerel and Horse Mackerel Egg Surveys (WGMEGS).

The main objective of this series of individual cruises from January until July is to produce both an index and a direct estimate of the biomass of the north east Atlantic mackerel stock and an index for the southern and western horse mackerel stocks. The results have been used in the assessment for mackerel since 1977 and from 1992 for horse mackerel. The mackerel and horse mackerel egg survey is the only source of data providing fisheries independent information for these stocks.

The general method is to quantify the freshly spawned eggs in the water column on the spawning grounds. To be able to establish a relationship between eggs and biomass of the spawning stock, the fecundity of the females must also be determined. This is undertaken by sampling sufficient numbers of ovaries before, during and after spawning. The potential fecundity is then counted from whole mount volumetric subsamples using a dissecting microscope while atresia is counted histologically from slides. Realised fecundity is estimated as potential fecundity minus atresia. The realised fecundity is used in combination with the calculated number of freshly spawned eggs in the water to render an estimate of the spawning stock biomass.

To provide reliable estimates of the quantity of spawned eggs and the fecundity an extensive coverage of the spawning area is required both in time and space. The spawning of the southern horse mackerel stock and the southern mackerel component starts in late December off the Portuguese coast. Spawning proceeds further north along the continental shelf edge as water temperature increases during late winter and spring. In the past the peak spawning has normally occurred in April-May in the area of the Sole Banks with an extension to the Porcupine Bank, however the most recent survey in 2010 saw peak spawning in February – March. Spawning is not restricted only to the areas and at the same time spawning can also be observed in the inner Bay of Biscay and extends as far north as the waters of the Faroese Islands.

This survey report presents the preliminary results of the 2013 mackerel and horse mackerel egg survey provided for WGWIDE in August 2013. The survey report and the analysis will be finalized during the next WGMEGS meeting in April 2014. Although every effort was made to ensure that WGWIDE were provided with the most recent and accurate data-set, WGMEGS cannot guarantee that there will not be changes before finalizing the analysis. This is due to the large numbers of plankton and fecundity samples to be analysed following the surveys, together with the extended survey time in 2013 and the tight deadline required by WGWIDE. This has resulted in a very limited processing time in 2013.

Survey effort

As a consequence of the long spawning period and the large survey area involved, the mackerel and horse mackerel egg surveys have always relied on wide international participation. In 2013 a total of 17 individual cruises were carried out with a total of 341 survey days, with the contribution of Spain (IEO: 49 days at sea, AZTI: 44 days), Scotland (71 days), Ireland (42 days), Portugal (14 days), Germany (36 days), the Netherlands (36 days), Norway (25 days), the Faroe Islands (13 days) and Iceland (15 days).

Survey design

The aim of the triennial egg survey is to determine the annual egg production (AEP) of both species. This is calculated using the mean daily egg production rates per pre-defined sampling period for the complete spawning area of the Northeast Atlantic Mackerel and Horse Mackerel Stocks. To achieve this, one plankton hauls per each half rectangle (separated by approximately 15 nm) is conducted on alternating transects covering the complete spawning area. The 2013 egg survey was designed in order to maximise both the spatial and temporal coverage in each of the sampling periods. Given the high variability in egg production by station this design ensures the smallest chances of under/overestimation of the egg production (ICES 2008).

In keeping with both 2010 and 2007, the survey was split into six sampling periods. The deployment of vessels to areas and periods is summarized in Table 1. Overall the vessel deployment and effort in 2013 was very similar to that of 2010.

The first period (January/February) was covered by a single extended Daily egg production (DEPM) survey in ICES area IXa only, with fuller coverage starting in period 2 (late February). No sampling took place in area IXa thereafter. Sampling of the western area commenced in period 2 which included coverage of the Cantabrian Sea and Galicia. Sampling in Galicia ceased after period 3. From period 5 onwards, only the western area north of the Cantabrian Sea was covered. Although some spawning was expected in the Cantabrian Sea during period 5, (as it has been surveyed at this time in earlier years) no vessels were available to survey it. In periods 5 and 6 the surveys were designed to identify a southern boundary of spawning and to survey all areas north of this boundary.

Maximum deployment of effort in the western area was during the second, third and fourth sampling periods. These periods coincided with the expected peak spawning of both mackerel and horse mackerel in the area. Due to the expansion of the spawning area which has been observed since 2007 the emphasis was even more focused on full area coverage and delineation of the spawning boundaries. Cruise leaders had been asked to cover their entire assigned area using alternate transects and then use any remaining time to fill in the missed transects.

Processing of samples

A total of 2061 plankton samples were taken and sorted. Mackerel and horse mackerel eggs were identified and the egg development stages determined. Depending on the vessel facilities and the experience of the participants this was done either during the cruise or in the home laboratories.

Double micropipette samples and slices from ovaries of mackerel and horse mackerel were also taken on board. After finishing the individual surveys these samples were sent to five different European research institutes for the histological analysis of realised fecundity (potential fecundity minus atresia). Because of the narrow time frame only a selection of the fecundity samples have been analysed up to this date. For the mackerel atresia analysis only fish with atretic oocytes or spawning markers can be used. These markers can only be reliably detected histologically. Thus the number of samples is dependent on the results from the screening sample analysis before we know which samples can be used for the histological process to estimate atresia.

The analysing of the plankton samples as well as of the fecundity samples were carried out according to the sampling protocols as described in the WGMEGS Survey Manual v1.2 (WGMEGS 2013, Annex 2).

Horse mackerel is considered to be an indeterminate spawner and therefore since 2007 IPIMAR has adopted the DEPM methodology for horse mackerel in the southern area. The egg survey design in the western area is directed at the AEP method for mackerel which produces an estimate of SSB. Fecundity samples for horse mackerel were taken during the survey in the western areas in order to develop a modified DEPM approach for estimating the biomass of the horse mackerel stocks.

Planned and realized survey coverage by period

Period 1 – In this period only the southern area between Cadiz and Galicia was surveyed by Portugal. This DEPM survey is mainly targeting the southern horse mackerel stock and designed for this purpose but providing mackerel egg samples as well. Due to significant operational problems with the survey vessel only 222 stations were sampled during 10 days compared to 414 samples in 2010. Despite this good spatial coverage was achieved and there were no interpolated samples. See figure 1.1 for numbers of completed samples/ sampling rectangle.

Period 2 - Period 2 marks the commencement of the western area surveys. In contrast to 2010 the start of period 2 was brought forward by 2 weeks starting in mid February in order to try and ‘capture’ spawning activity early in the season. Sampling was undertaken by Ireland (Celtic Sea and N Biscay), Spain (IEO: Galicia, Cantabrian Sea and Bay of Biscay) and Scotland (Northwest Ireland and West of Scotland).

Massive spawning was observed in the Biscay area and to a lesser degree up into the Celtic Sea and also from Galicia through to the Cantabrian Sea in the south and west. Spawning was observed throughout the remainder of the survey area though at very low levels west of Scotland and also over the Rockall Plateau. Survey coverage was good with 406 stations sampled and 55 interpolations. There were 50 replicate samples which were predominantly completed in the Cantabrian Sea. See figure 1.2 for numbers of completed samples/ sampling rectangle.

Period 3 – In period 3 the German vessel was operating in the West of Ireland, Celtic Sea and N Biscay. Northwest Ireland and the West of Scotland were covered by Scotland, the Bay of Biscay,the Cantabrian Sea and Galicia by Spain (IEO and AZTI).

Significant spawning was reported from throughout the survey area for this period and was particularly high in the Cantabrian Sea. Otherwise the highest concentrations were found along the shelf edge but to the west of Scotland low level spawning were observed as far as 17°W. Significant disruption was experienced in this period. Operational vessel issues resulted in a loss of 4 days and severe weather in the Celtic Sea / Northern Biscay area resulted in another 12 days of survey time being lost. Despite the disruption experienced, good coverage was achieved throughout during this period although north of 54°N only alternate transects were sampled. 432 stations were sampled and there were 132 interpolations. There were 33 replicate samples which once again were predominantly completed in the Cantabrian Sea. See figure 1.3 for numbers of completed samples/ sampling rectangle.

Period 4 – This period was covered by three dedicated mackerel egg surveys. The Dutch vessel was operating in the Celtic Sea and Biscay. West of Scotland and Irish waters were covered by the Norwegian vessel with the Faroese vessel extending the survey boundary north of this. In addition AZTI carried out a targeted DEPM survey for anchovy in the Biscay and Cantabrian Sea and although it provides mackerel and horse mackerel egg samples as well, the design of this survey is constrained in that purpose.

Continuous low levels of spawning were observed throughout the whole survey area. The westerly expansion to west of Scotland of the mackerel spawning area seen in period 3 continued in period 4 and also around the Faroese area. Coverage was good although the expansion of the survey area in the northwest resulted once more in only an alternate transect survey being completed north of 52°N. 417 stations were sampled and there were 171 interpolations. Only 10 replicate samples were taken and these were collected from the Cantabrian Sea. During this period 5 days were lost through a combination of severe weather and vessel issues. See figure 1.4 for numbers of completed samples/ sampling rectangle.

Period 5 – In period 5, the Netherlands, Scotland and Iceland covered the entire spawning area from Biscay (46°N) to the West of Scotland up to Icelandic waters at around 63°N.

Surveying in the Biscay area commenced at 46°N and successfully delineated the southern boundary of spawning for this period. Elsewhere within period 5 spawning activity was very widely dispersed and at very low levels throughout the entire survey area. This extended past 20°W to the west of Scotland and to a similar extent in the Northern area around the Faroe Islands and Iceland. Overall, survey coverage was good although almost exclusively undertaking alternate transect sampling methodology in order to ensure adequate geographical coverage. Despite this several western boundaries remained unsecured. 448 stations were sampled and there were 243 interpolations. There were no replicate samples taken. See figure 1.5 for numbers of completed samples/ sampling rectangle.

Period 6 – This period was covered entirely by Ireland sampling on alternate transects in the area from 47°15N in the South to the most northern transect on 58°15N.

The southern boundary of sampling was delineated at 50°N and only very low levels of spawning were observed during this period. In contrast to previous years the survey was able to define a northern spawning boundary at 58°N. 133 stations were sampled with 29 interpolations. There were no replicate stations completed. See figure 1.6 for numbers of completed samples/ sampling rectangle.

Table 1. Participating countries, vessels, areas assigned, dates and sampling periods of the 2013 surveys.

Country	Vessel	Areas	Dates	Period
Portugal	D. Carlos I	Cadiz, Portugal & Galicia	10th Feb – 19th Feb	1
Spain (IEO)	Angeles Alvarino	Cantabrian Sea & Biscay	7th Mar – 29th Mar	2
		Biscay & Cantabrian Sea	1st Apr – 22nd Apr	3
Germany	W. Herwig III	West Ireland & Celtic Sea	27th Mar – 22nd Apr	3
Netherlands	Tridens	Celtic Sea	7th May – 22nd May	4
		Celtic Sea & Biscay	3rd June – 18th June	5
Spain (AZTI)	R/V ANGELES ALVARIÑO	Biscay	22nd Mar – 6th Apr	3
	Margalef	Biscay & Cantabrian Sea	13th May – 4th June	4
Norway	MS EROS	West Ireland & West of Scotland	14th May – 5th June	4
Ireland	Celtic Explorer	Celtic Sea & Biscay	18th Feb – 10th Mar	2
		Celtic Sea, West Ireland & West of Scotland	15th July – 31st July	6
Scotland	Scotia (IBTSQ1)	West of Scotland	20th Feb – 2nd Mar	2
	ALTAIRE	NW Ireland & West of Scotland	14th Mar – 27th Mar	2
	Scotia	West of Ireland & West of Scotland	19th Apr – 7th May	3
	Christina S	West of Ireland & West of Scotland	4th June– 24th June	5
Faroe Islands	Magnus Heinason	Faroes & Shetland	23rd May – 2nd June	4
Iceland	Bjarni Saemundsson	Faroes & Shetland	11th June– 26th June	5

Figure 1.1: Number of observations per rectangle in period 1 (10th February – 19th February) and the country assigned areas (shaded).

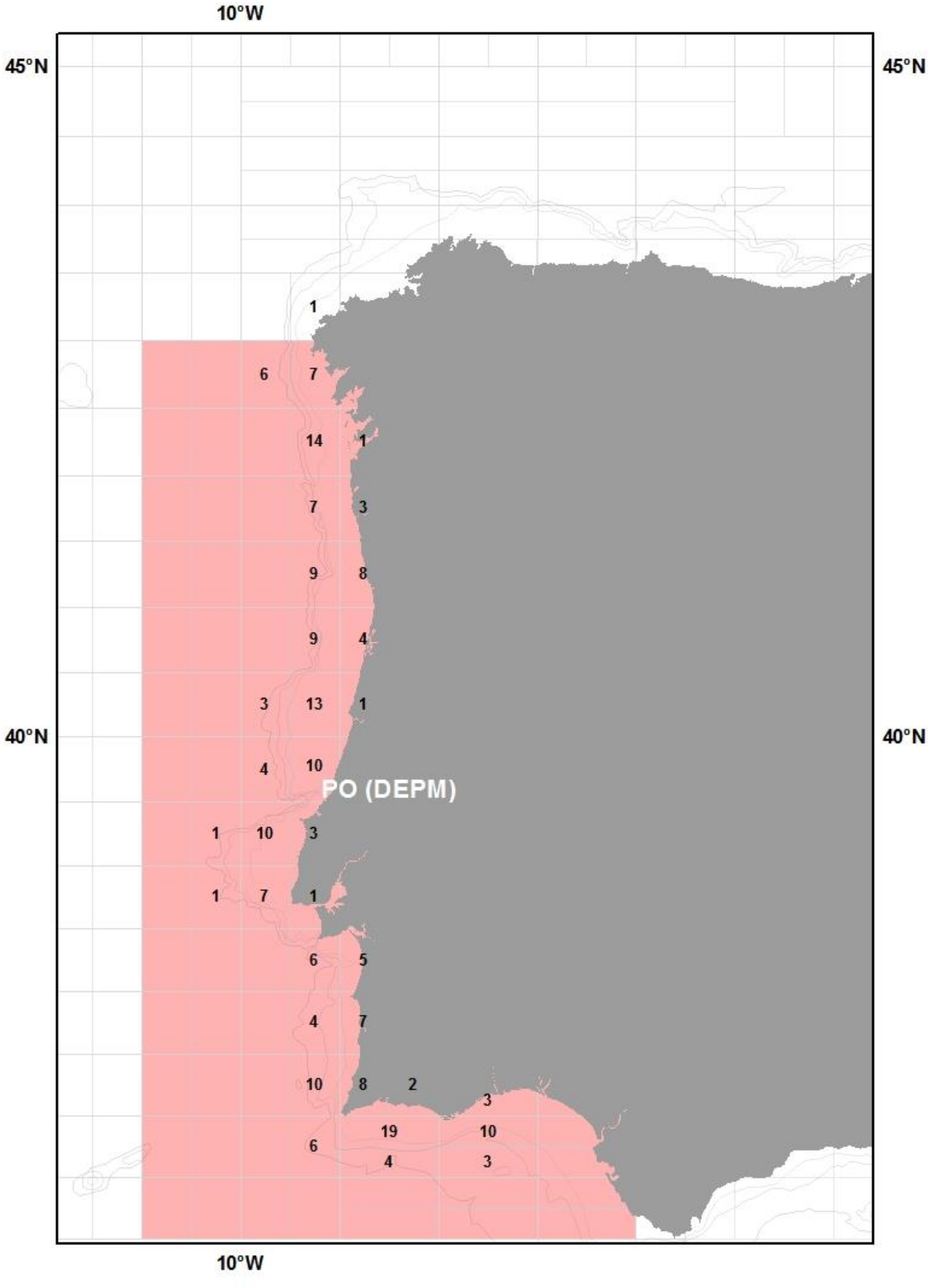


Figure 1.2: Number of observations per rectangle in period 2 (19th February – 27th March) and the country assigned areas (shaded) - X represents interpolated rectangles.

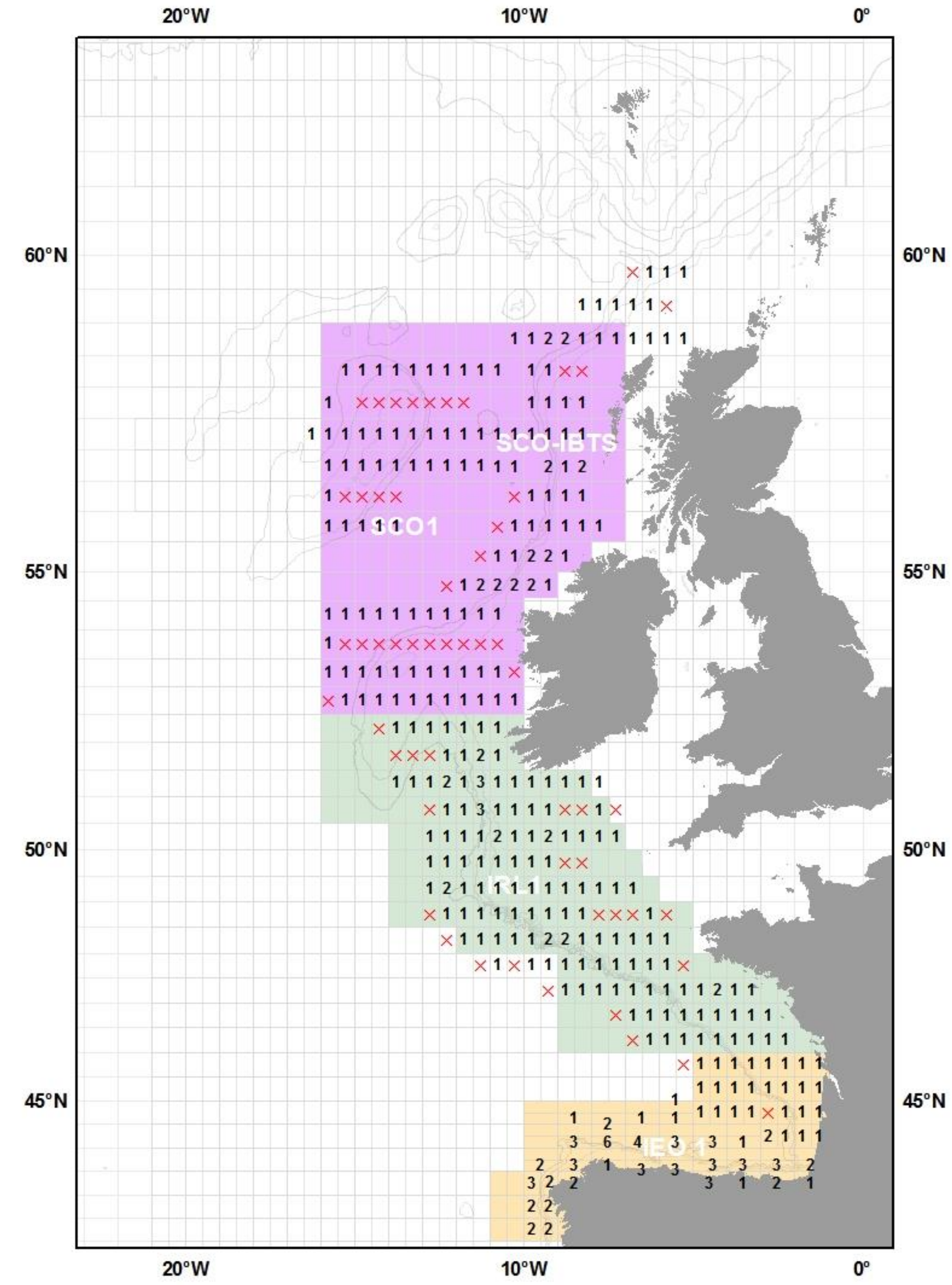


Figure 1.3: Number of observations per rectangle in period 3 (28th March – 6th May) and the country assigned areas (shaded) – X represents interpolated rectangles.

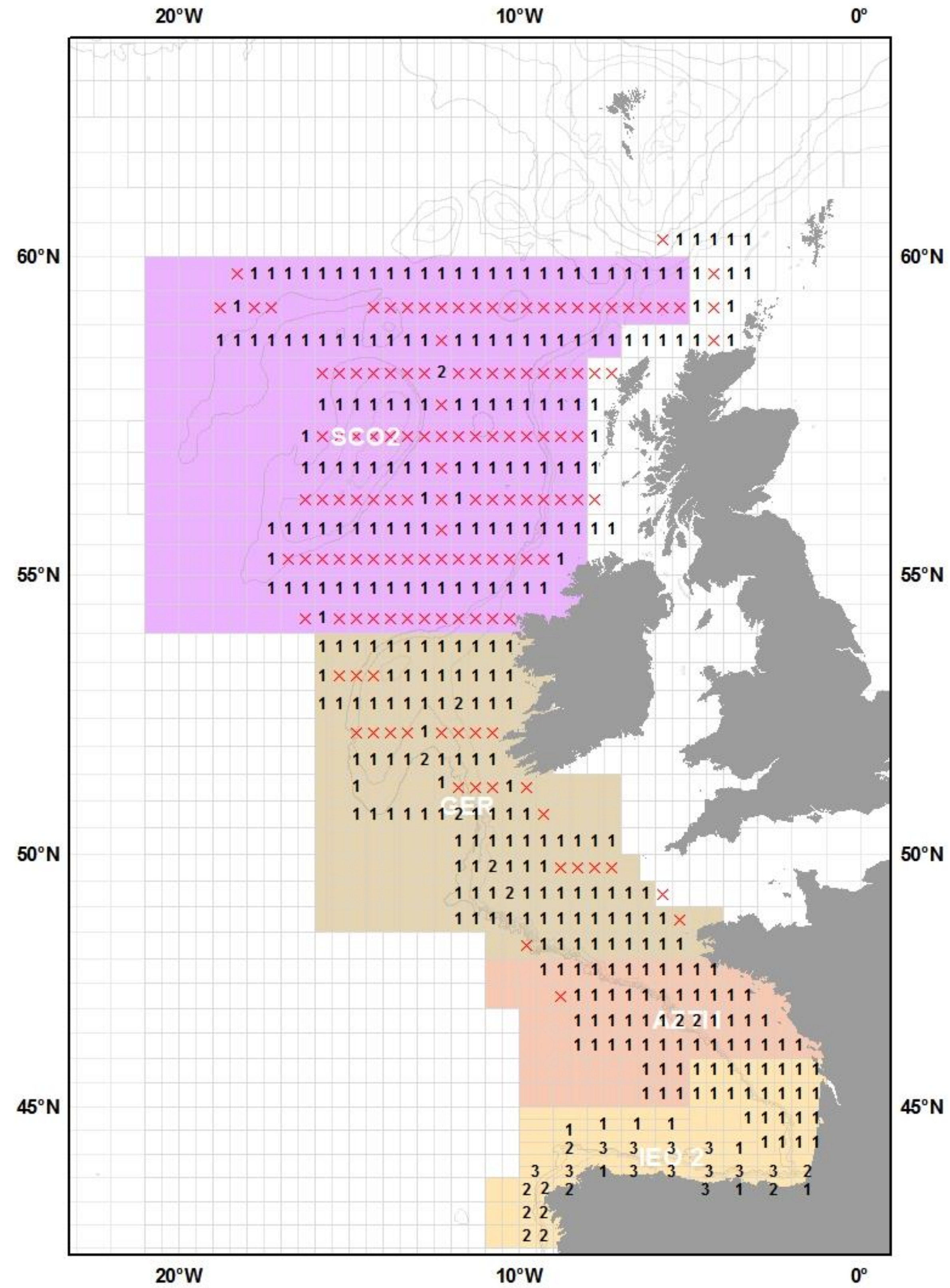


Figure1.4: Number of observations per rectangle in period 4 (7th May – 3rd June) and the country assigned areas (shaded) – X represents interpolated rectangles.

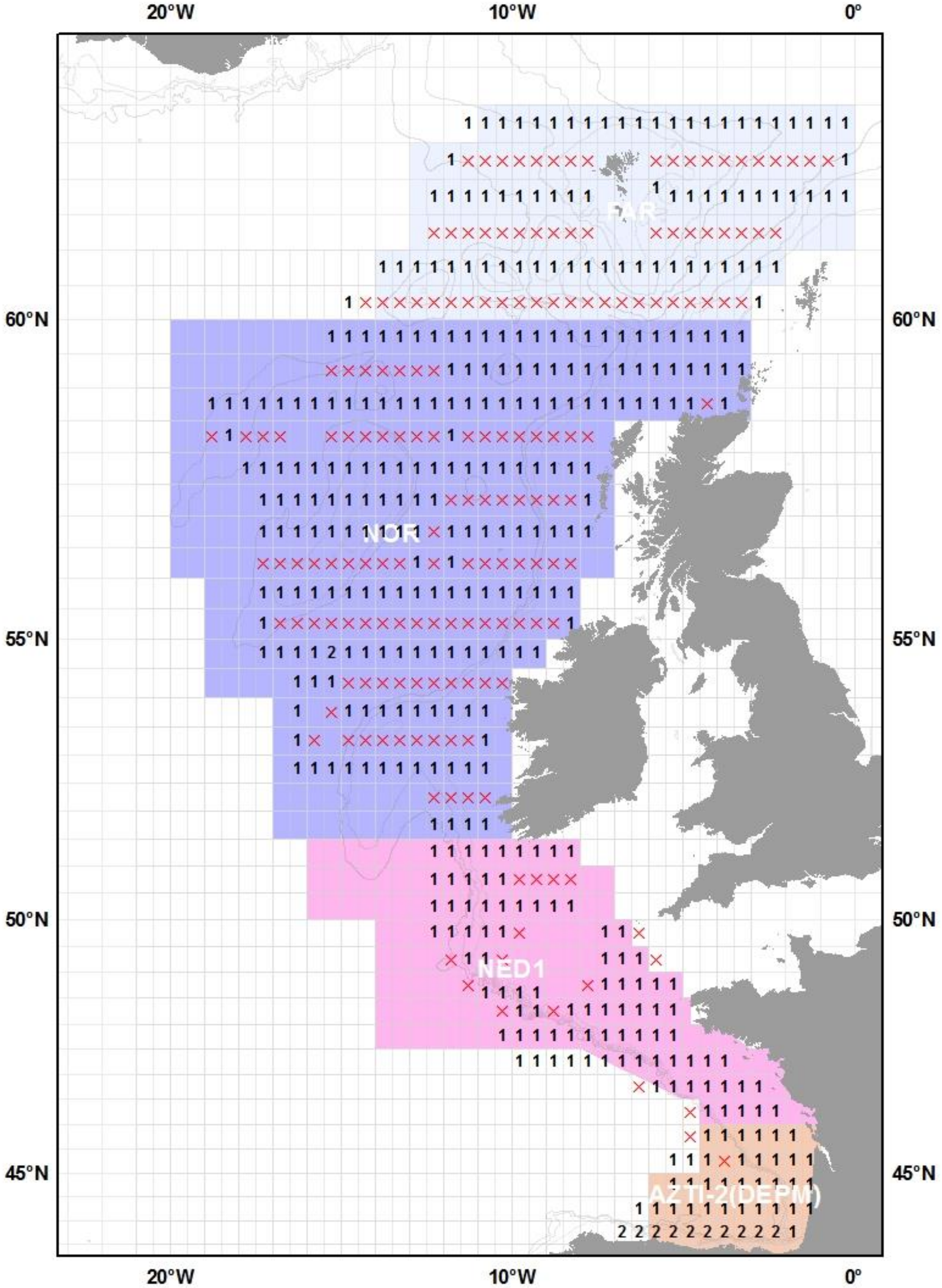


Figure 1.5: Number of observations per rectangle in period 5 (4th June – 26th June) and the country assigned areas (shaded) – X represents interpolated rectangles.

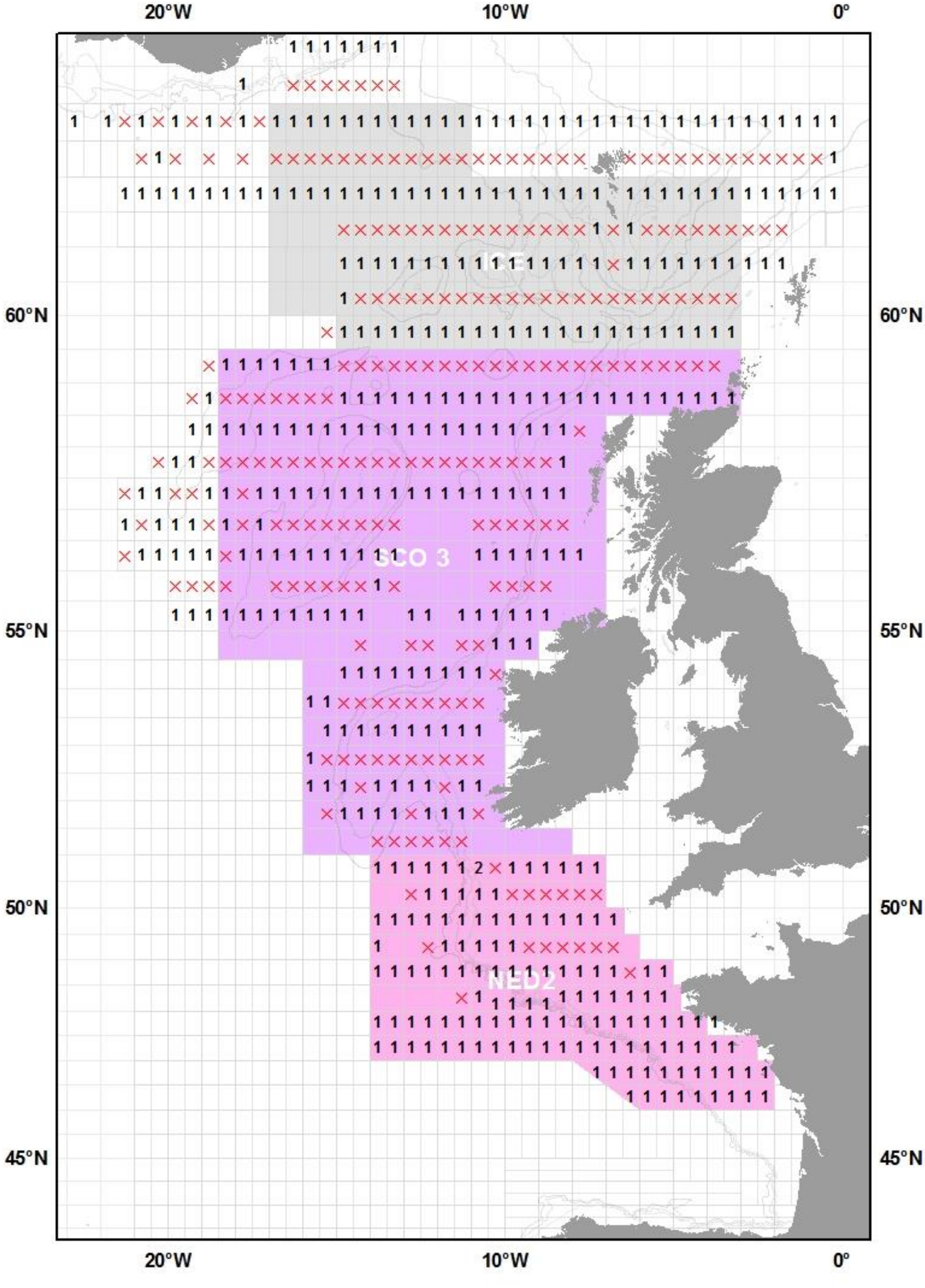
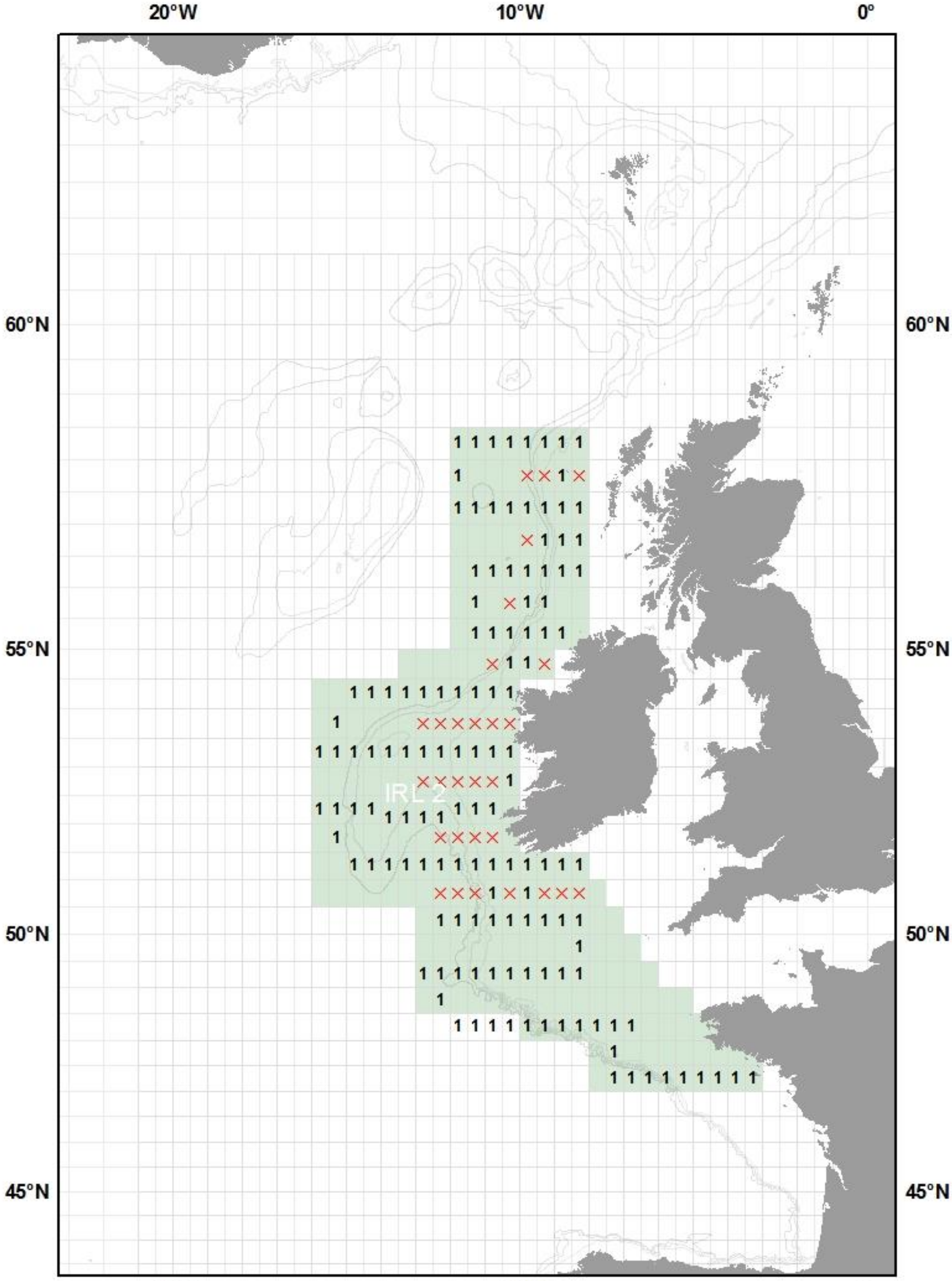


Figure 1.6: Number of observations per rectangle in period 6 (15th July – 31st July) and the country assigned areas (shaded) – X represents interpolated rectangles



Results - MACKEREL

Stage 1 Egg production in the Western Areas

Figure 2.1 represents the egg production curve for the western area for the 2013 survey, along with those for the previous surveys for comparison. 2010 provided an unusually large spawning event early in the spawning season, but in 2013 an even larger spawning event has been observed that provides evidence that spawning is almost certainly taking place well before the nominal start date of 10th February (day 42). The nominal end of spawning date of the 31st July is also the same as that used in previous years and the shape of the production curve during this period does not suggest that the chosen end date should be altered. Production estimates for the individual survey periods and the period before the surveys are presented in table 2. The survey periods were not completely contiguous and this has been accounted for in table 2. The standard error has not yet been calculated, but because of the increase in survey area and a greater subsequent number of interpolated samples the expectation is that it will be larger compared to 2010. The provisional total annual egg production (TAEP) for the western area in 2013 was calculated as $\mathbf{2.31 \times 10^{15}}$. This is a 27% increase on the 2010 TAEP which was 1.69×10^{15}. The spawning curve is very similar to that observed in 2010 which displayed the largest spawning event in the first sampling period of the western area. Period 2 and pre period 2 egg production accounted for 70% of the overall egg production in the western area in 2013.

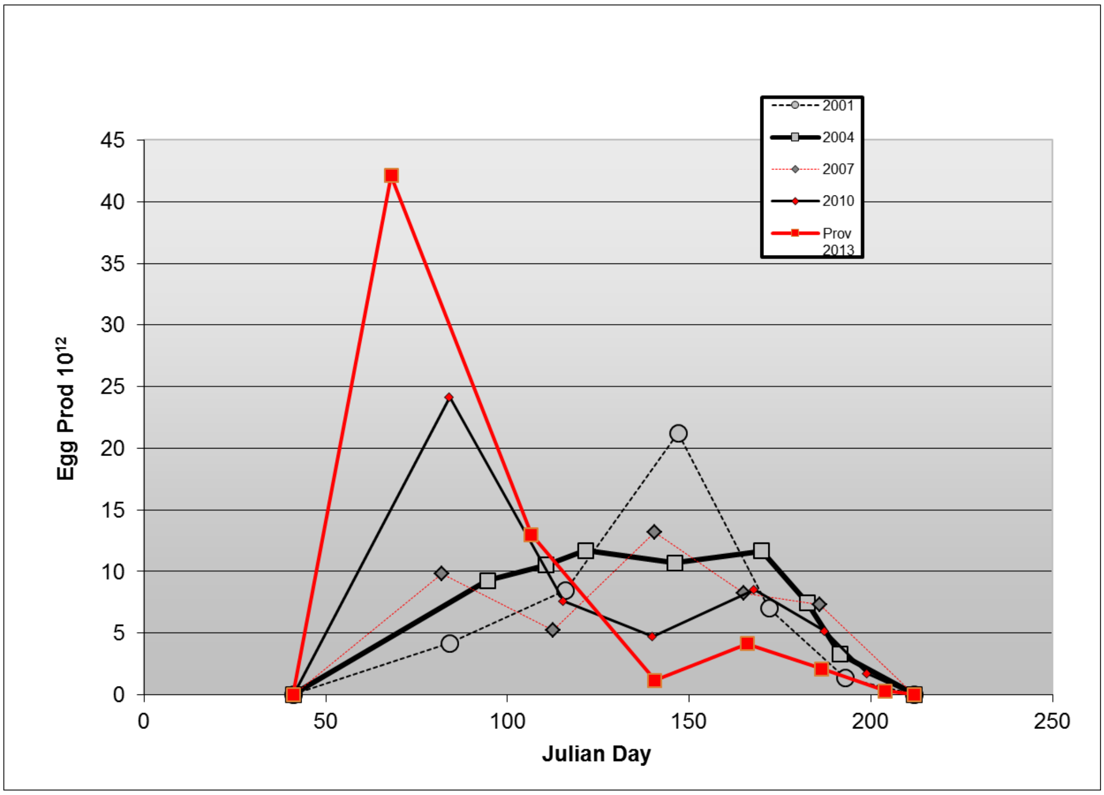


Figure 2.1: Provisional annual egg production curve for mackerel in the western spawning component. The curve for 2001, 2004, 2007 and 2010 are included for comparison.

Table 2.: Western estimate of mackerel total stage I egg production by period using the histogram method for 2013.			
Dates	Period	Days	Annual stage I egg production x 10^{15}
< 19 Feb	Pre2	9	0.06
19 Feb – 27 March	2	37	1.56
28 March – 6 May	3	40	0.152
7 May – 3 June	4	28	0.03
4 June – 26 June	5	23	0.09
27 June – 14 July	*	18	0.03
15 July – 31 July	6	17	0.005
Total	2.31		

Stage 1 Egg production in the Southern Areas

Figure 2.2 presents the egg production curve for the southern area for the 2013 survey, along with those for previous surveys for comparison. Total egg production values by survey period are displayed in table 3. The start date for spawning in the southern area was the 30th January and is the same as was used in 2010and is based on the occurrence of stage I eggs found off the Portuguese coast during the period 1 survey. The same end of spawning date of the 17th July was used again this year and the spawning curve suggests that there is no reason for this to change. Production estimates for the individual survey periods and the period before the surveys are presented in Table 3. As with 2010 the survey periods were not completely contiguous and this has been accounted for in table 3. The provisional total annual egg production (TAEP) for the southern area in 2013 was calculated as **6.77×10^{14}**. This is a 59% increase on the 2010 TAEP which was 4.26×10^{14}. In contrast to both the 2007 and 2010 results peak spawning has moved back from period 2 to period 3 (28th March – 6th May).

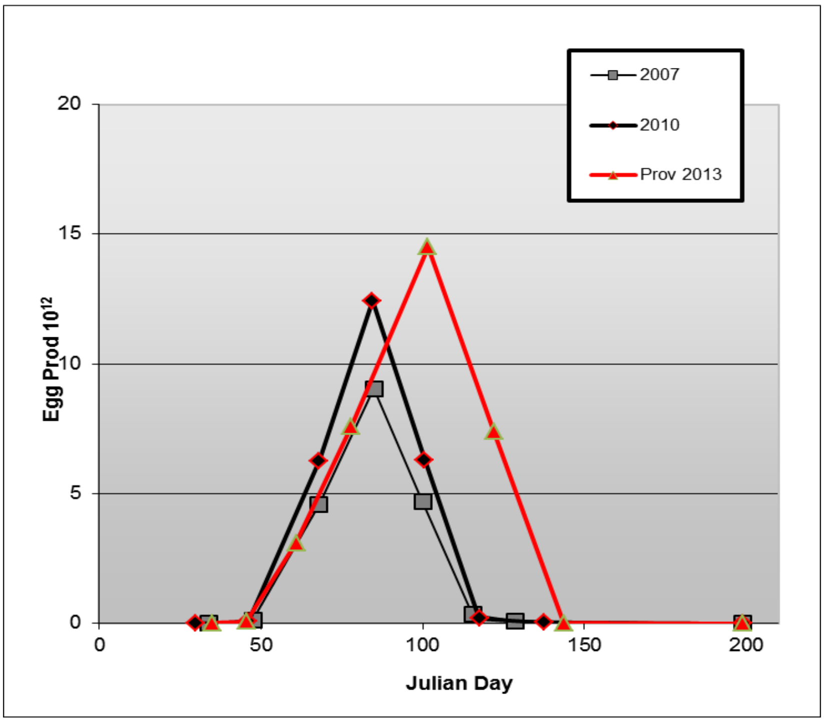


Figure 2.2: Provisional annual egg production curve for mackerel in the southern spawning component for 2013. The curve for 2007 and 2010 are included for comparison.

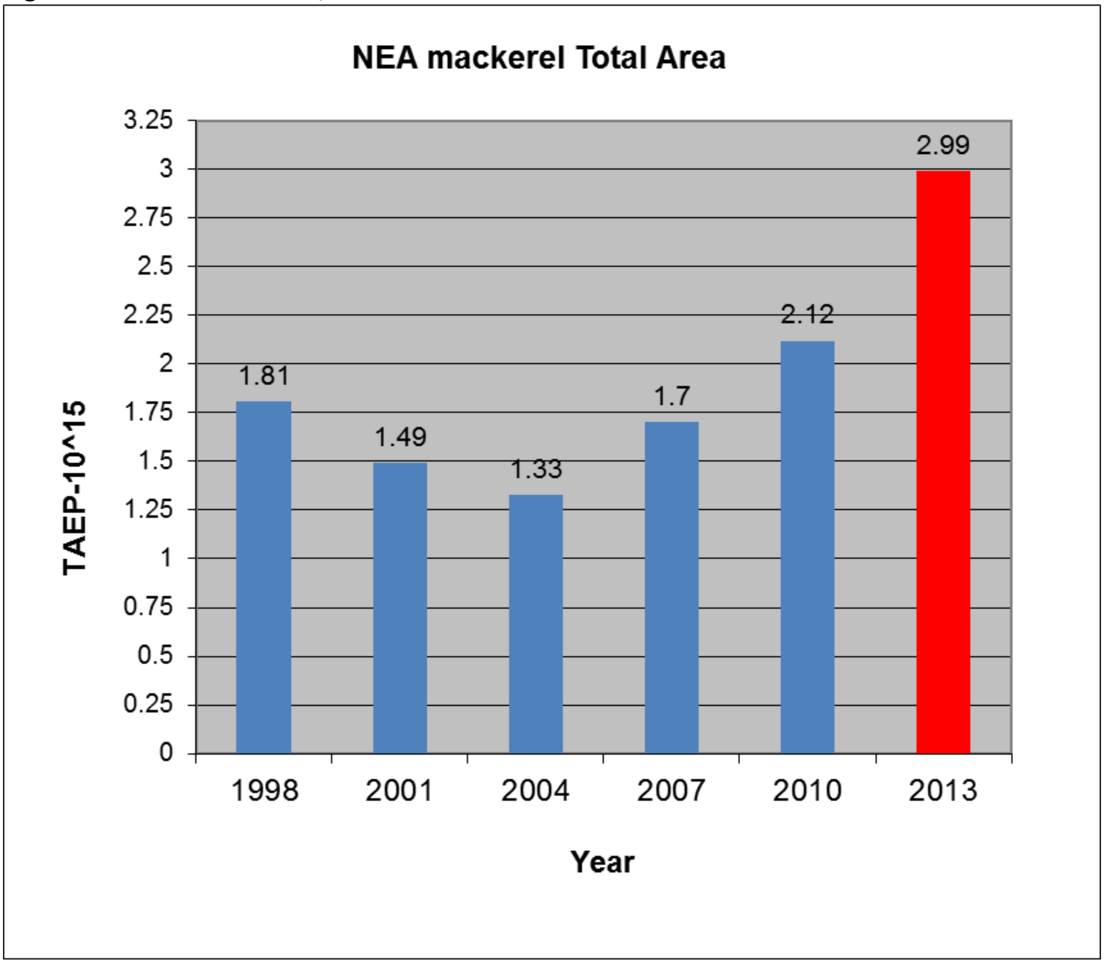
Table 3.: Southern estimate of mackerel total stage I egg production by period using the histogram method for 2013. .

Dates	Period	Days	Annual stage I egg production x 10^{14}
30 Jan – 9 Feb	Pre 1	11	0.003
10 Feb – 19 Feb	1	10	0.008
20 Feb – 12 Mar	*	21	0.71
13 March – 31 Mar	2	19	1.44
1 April – 22 April	3	22	3.19
23 April – 11 May	*	19	1.41
12 May – 4 June	4	24	0.003
5 June – 18 July	*	44	0.002
Total	6.77		

Total egg production

Total annual eggs production (TAEP) for both the western and southern components in 2013 is **2.99 *10^{15}** · This equates to a net increase in production of **29%** compared to 2010. Figure 2.3 below displays the historical TAEP of NEA Mackerel back as far as 1998.

Figure 2.3: TAEP estimates, 1998 – 2013.



Egg abundance plots displaying the spatial distribution of stage 1 mackerel eggs / period are presented for both the southern and western areas together and can be found in Annex 1, figures 1 – 6.

Fecundity estimates

Samples used

Fecundity samples have to be analysed in the laboratory upon return from sea and the procedures for analyses are time consuming. The last samples were collected in July and thus not all samples could be analysed for this preliminary report, but enough samples are analysed to give a preliminary estimate of mackerel fecundity in 2013.

Previous preliminary estimates have been based on samples taken in period 1 and 2, while for 2013 period 2 and 3 were used. The reason for that change was that the histological screening samples for period 1 were incorrectly stored in meshed cassettes in communal containers that allowed mixing of samples, and thereby made these samples useless.

Screening

For potential fecundity counts whole mount samples taken from maturing female mackerel which had not started spawning were used. In previous surveys spawning status was evaluated from the whole mount samples under the dissecting microscope, while this year the whole mount evaluation was preceded by a histological screening. The procedure using only whole mount samples was error prone due to difficulties in identifying and scoring the presence of postovulatory follicles (POF'), which are an important spawning marker. POF´s can be detected much more reliable using histology. Due to this extra histological screening, this year's whole mount analysis has a considerable higher reliability.

POF scoring using histology (Table 4) proved to be rather uniform between the institutes; all institutes detected POF´s in 65-75% of the samples.

Table 4. POF scoring using histology by institute

POF present	Institute 1	Institute 2	Institute 3	Institute 4
No	55	54	75	75
Yes	142	159	140	142
Yes (%)	**72.1**	**74.6**	**65.1**	**65.4**

The screening is also used to detect atretic oocytes in the samples. Samples with atretic cells were marked and used for the atresia estimation.

Potential fecundity

For the 2013 preliminary estimate of potential fecundity 90 samples were available, which was 19% of all the samples screened for period 2 and 3. As for the final potential fecundity estimate of the 2010 survey (ICES 2011) standard limits on fish condition (Fulton K) and relative fecundity (n/g fish) were used to remove outlier values (Figure 3). Of the 90 samples two were discarded due to unreasonable high relative fecundity values (Figure 3). All but one laboratory produced very similar fecundity estimates (Table 5). One laboratory delivered results (from 10 samples) that were 15% higher compared to the average for the other laboratories (t-test showed that the difference was significant on the 95 % level, P = 0.049). However, calculations showed that inclusion of these results only had a small effect on the mean fecundity (1248 versus 1227n/g fish). Apart from being 15% higher than the other laboratories there are no indications that these results are wrong and thus they were included in the final estimate.

Table 5. Potential relative fecundity (n/g fish) by institute and total.

Institute	Mean	N	sd	min	max	p50	95 % CI
1	1192	13	218	761	1555	1177	1061-1324
2	1413	10	229	1119	1696	1358	1249-1577
3	1227	17	423	387	2052	1194	1009-1445
4	1271	28	242	792	1884	1296	1177-1365
5	1187	20	319	506	1724	1192	1038-1336
Total	**1248**	**88**	**300**	**387**	**2052**	**1247**	**1184-1312**

Because the fecundity samples from period 1 could not be used period 3 samples were included instead. The estimate for period 3 was however 8% lower than for period 2 (Table 6). Compared to an estimate based on samples from period 2 alone the inclusion of samples from period 3 reduced the final potential fecundity estimate by 3%, - from 1284 to 1248n/g fish.

Table 6: Relative potential (n/g fish) fecundity by period

Period	Mean	N	sd	min	max	p50
2	**1284**	56	299	506	2052	1262
3	**1185**	32	296	387	1626	1191
Total	**1248**	88	300	387	2052	1247

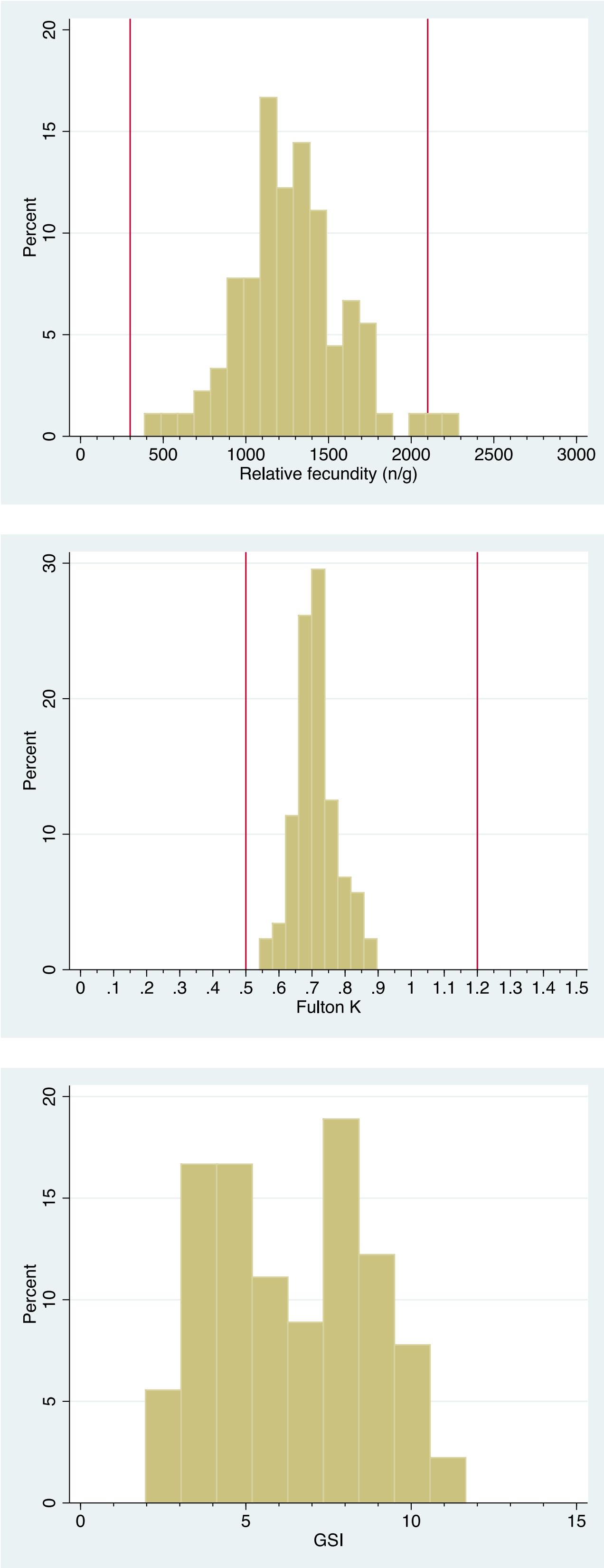


Figure 3. Upper panel: Frequency histogram of relative fecundity (n/g fish). Red lines marks limits for outlier discrimination. Middle panel: Frequency histogram of fish condition (Fulton K), red lines marks limit for outlier discrimination). Lower panel: Frequency histogram of gonadal somatic index (GSI).

Atresia

Atresia is the loss of oocytes by reabsorption before spawning and is to be subtracted from the potential fecundity (whole mount fecundity counting) to get the realised fecundity. Because the histology screening before the whole mount analysis is time consuming it has not been possible for this preliminary report to analyse samples for the intensity of atresia. The histological screening has however given us an estimate on the prevalence of atresia, which may be a good indicator of the level of atresia.

Prevalence of atresia is in this survey defined as the percentage of spawning fish which have early stage atresia (early alpha-atresia). Among the 566 spawning fish that were analysed in the histological screening, 25% were found to have early atresia. This is on the same level as the 4 previous surveys (Table 7, 20-38%).

Realised fecundity

Realised fecundity is defined as the potential fecundity minus the loss by atresia. The loss by atresia is a function of both intensity of atresia and prevalence of atresia. Since no 2013 results on the intensity of atresia are available yet the average loss from the surveys going back to 2001 (Table 7) was used to calculate realised fecundity. In this period the relative loss by atresia ranged from 6-9% (average 7%).

The preliminary realised fecundity estimate for 2013 was calculated to be 1161 oocytes/gram fish. Table 7 summarizes historical reproductive parameters estimated since 1998.

Table 7. Mackerel fecundity and atresia by assessment year.

	Assessment year					
Parameter	**1998**	**2001**	**2004**	**2007**	**2010**	**2013 preliminary**
Number of samples used for estimation of fecundity (n)	96	187	205	176	74	88
Number of samples analyzed for atresia (n)	112	290	348	416	511	
Relative potential fecundity (n/g)	1206	1097	1127	1098	1140	1248
Prevalence of atresia	0.55	0.2	0.28	0.38	0.33	0.25

Geometric mean relative intensity of atresia (n/g)	46	40	33	30	26	
Potential fecundity lost per day (n/g)	3.37	1.07	1.25	1.48	1.16	
Potential fecundity lost per spawning season (n/g)	202	64	75	89	70	
Relative realized fecundity (n/g)	**1002**	**1033**	**1052**	**1009**	**1070**	**1161**
Percentage of relative potential fecundity lost	17	6	7	9	6	

Biomass estimation
Total spawning stock biomass (SSB) was estimated using the fecundity estimate of 1161 oocytes/g female, a sex ratio of 1:1 and a raising factor of 1.08 (ICES, 1987) to convert pre-spawning to spawning fish. This gave an estimate of spawning stock biomass of:
- 4,3 million tonnes for western component (2010: 3,4).
- 1,259 million tonnes for southern component (2010: 0,858).
- 5,56 million tonnes for western and southern components combined (2010: 4,289).

Figure 4 below provides a time series of mackerel SSB based on egg survey data compared with the ICA assessment.

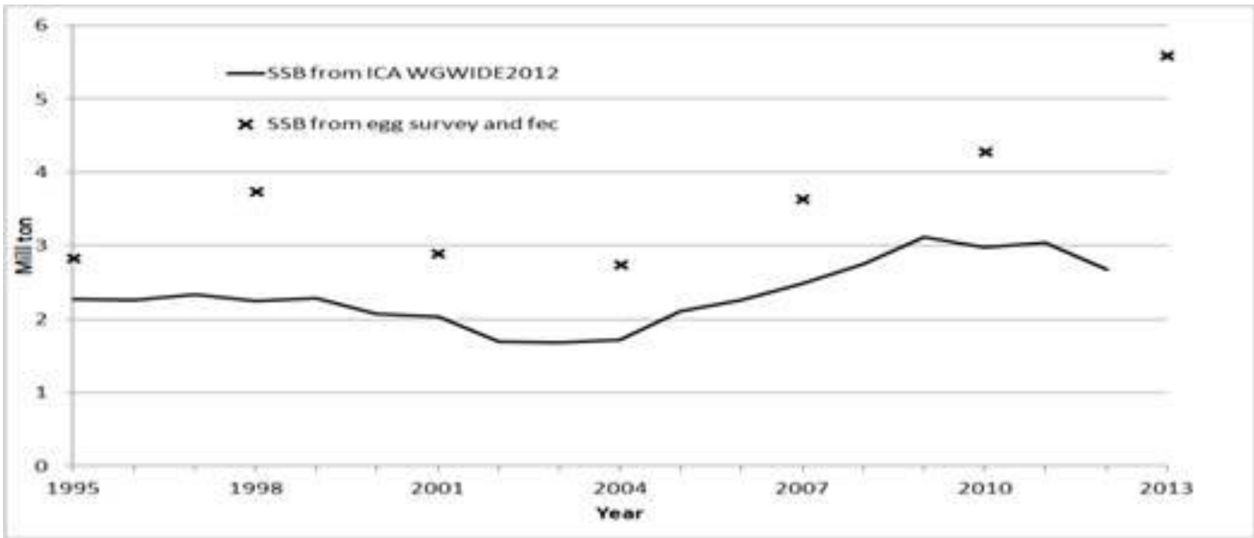


Figure 4. Time series of mackerel SSB based on egg survey data and the ICA assessment.

Results – HORSE MACKEREL

TAEP results – Western Horse Mackerel

Fig. 5.1 displays the mean daily stage I egg production estimates (DEP) for each survey period plotted against the mid-period days. The results of previous surveys are also included in the figure for comparison. Period production estimates are presented in Table 8. Period number and duration are the same as those used to estimate the western mackerel stock, as are the dates defining the start and end of spawning. The shape of the egg production curve does not suggest that those dates should be altered for 2013 although it seems likely that some spawning will continue after the end of July. Integration utilising the histogram method (multiplying daily egg production estimate by period duration) revealed an estimate of total annual egg production of **3.95 x 10^{14}**. This is a decrease of almost **64%** on 2010 which was 1.09 × 10^{15} and is one of the lowest estimates of annual egg production ever recorded for this species.

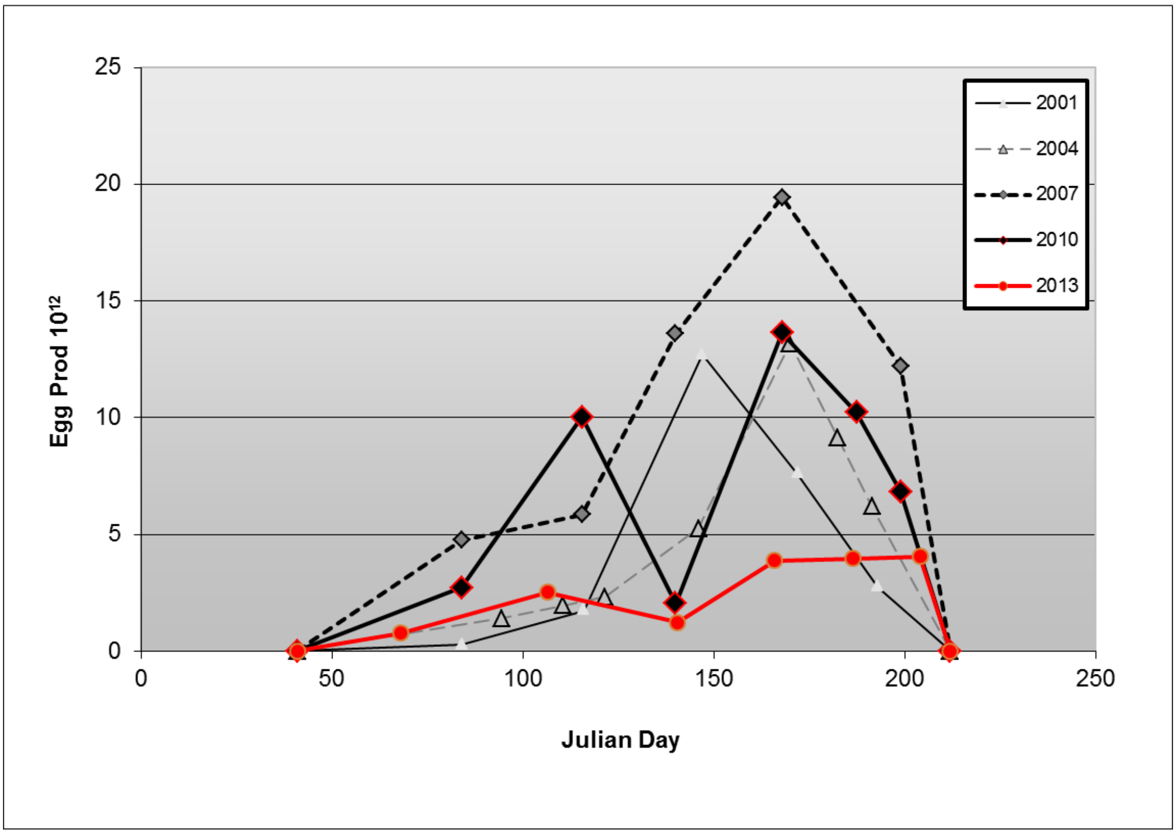


Figure 5.1: Provisional annual egg production curve for western horse mackerel. The curves for 2001, 2004, 2007 and 2010 are included for comparison.

Table 5.: Western estimate of horse mackerel total stage I egg production by period using the histogram method for 2013 .

Dates	Period	Days	Annual stage I egg production x 10^{15}
< 19 Feb	Pre2	9	0.001
19 Feb – 27 March	2	37	0.03
28 March – 6 May	3	40	0.1
7 May – 3 June	4	28	0.034
4 June – 26 June	5	23	0.09
27 June – 14 July	*	18	0.072
15 July – 31 July	6	17	0.069
			0
Total	0.395		

Egg abundance plots displaying the spatial distribution of stage 1 western horse mackerel eggs are presented for periods 2 – 6 and these can be found in Annex 1, figures 7 – 11.

DEPM results –Western Horse Mackerel

The horse-mackerel egg data of the DEPM survey are still under revision. Data are expected to be analyzed prior to the next WGMEGS meeting and results will be presented at the 2014 WGMEGS meeting.

Fecundity investigations

This year for horse mackerel only DEPM ovary samples were collected in period 5 at the peak of spawning. Since horse mackerel fecundity is at this moment not used for estimating the spawning stock biomass the focus of the fecundity analysis has been on mackerel. Therefore, at this time no horse mackerel fecundity results are ready to be presented. All samples will be analysed and results presented at the 2014 WGMEGS meeting.

Discussion

Since 2004 and subsequent to demands for up-to-date data for the assessment WGMEGS aims to provide an estimate of NEA mackerel biomass and western horse mackerel egg production in time for the assessment meetings within the same calendar year as the survey. This report represents the preliminary results of the 2013 egg survey. WGMEGS cannot guarantee that there will be no changes by finalizing the survey results in April 2014. However, according to the survey participants despite the tight deadline all plankton samples were analysed for mackerel (southern and western area) and horse mackerel (only western area) stage 1 eggs, so no samples which were taken but not analysed are missing in the station grid. Therefore if any, only negligible changes in the total egg production values are to be expected.

The fecundity results from the different participating labs have been examined to check the homogeneity in the analyses of the samples. There are differences between the institutes in the histology screening and fecundity counting that need to be investigated further. However, sensitivity tests indicate that these differences only have minor impact on the preliminary fecundity estimate.

No fecundity samples from period 1 were available, instead samples from period 3 were included in the potential fecundity estimate. Previous preliminary reports have only used fecundity data from period 1 and 2. In the 2007 and 2010 surveys period 3 fecundity samples had lower values compared to period 1 and 2. Between the two first periods, period 2 had the highest estimate in 2007 while in 2010 period 1 was the highest. From these comparisons it is likely that the inclusion of period 3 as a replacement for period 1 has reduced the fecundity estimate. However, a combined period 2 and 3 estimate for the 2013 survey is only slightly (3%) lower than a period 2 only estimate (Table 3).

For the final fecundity estimate the later periods will also be included, as was done for the 2010 survey. The 2010 survey showed that the relative fecundity estimate for period 1-6 was 2% lower than for period 1-2. The later periods also include samples from higher latitudes. The inclusion of period 3 for this preliminary fecundity estimate will improve the preliminary estimate and will reduce the difference between the preliminary estimate and the final estimate.

No estimate of loss by atresia is yet available for 2013. The realised fecundity estimate is therefore based on the average atretic loss found in the period from 2001-2010, which was 7%. Since the atretic loss has always been a small number compared to the potential fecundity, using this average value will likely not give a large error. The prevalence of atresia for 2013 (25%) is within the interval found for the four previous survey estimates (Table 4, 20-38 %), it is thus highly likely that the atretic loss will also be at the same level. Atretic loss will however be analysed and included in the final fecundity estimate at the WGMEGS meeting in 2014.

Mackerel egg production for period 1 in the Southern area (Portuguese DEPM survey) are given as *Scomber* spp. due to species mixing of *Scomber scombrus* and *Scomber colias*. This might lead to a slight overestimation in this most southern area. As the period 1 sampling is only contributing less than 1% of the TAEP for the southern mackerel the impact on the estimate is negligible. Overall egg production in the southern area increased by 59% compared to 2010.

Despite severe weather that was encountered during large periods of the 2013 survey program coupled with significant technical problems experienced on several of the participating vessels the 2013 Triennial egg survey was successful in providing comprehensive coverage of the spawning areas of both mackerel and horse mackerel. Whilst the expansion of the mackerel spawning area in periods 3 - 5 continues to be a concern, the egg production in these areas compared to the main areas of peak spawning in period 2 remain low. 2010 also witnessed an early peak of spawning although this was eclipsed by the magnitude of the spawning event during the same period in 2013. Despite surveying in the western area beginning 2 weeks earlier compared to 2010 there is a real necessity for sampling in the western area to begin as much as a month earlier in order to ensure that the peak of spawning is not missed. In 2013 the peak of spawning was not only significantly larger but it was also earlier than in 2010. It is impossible to predict the future spawning movements of mackerel and especially so during a triennial survey program however with the last 2 surveys now providing compelling evidence of early peak spawning within an expanding stock it would seem a logical proposition if the additional resources can be found. It is recommended that in the years between the surveys that eggs and fecundity samples are collected (utilising opportunities on existing annual surveys) and analysed in order to better understand the development of fecundity and egg production, thus enabling WGMEGS to predict when spawning will commence in 2016, thus ensuring that the next MEGS survey in 2016 is well placed to adequately survey peak spawning.

Annex 1

Figure 1: Mackerel spp. egg production by half rectangle for period 1 (10th February – 19th February). Filled blue circles represent observed values, filled red circles represent interpolated values, black crosses represent observed zeroes,red crosses interpolated zeroes.

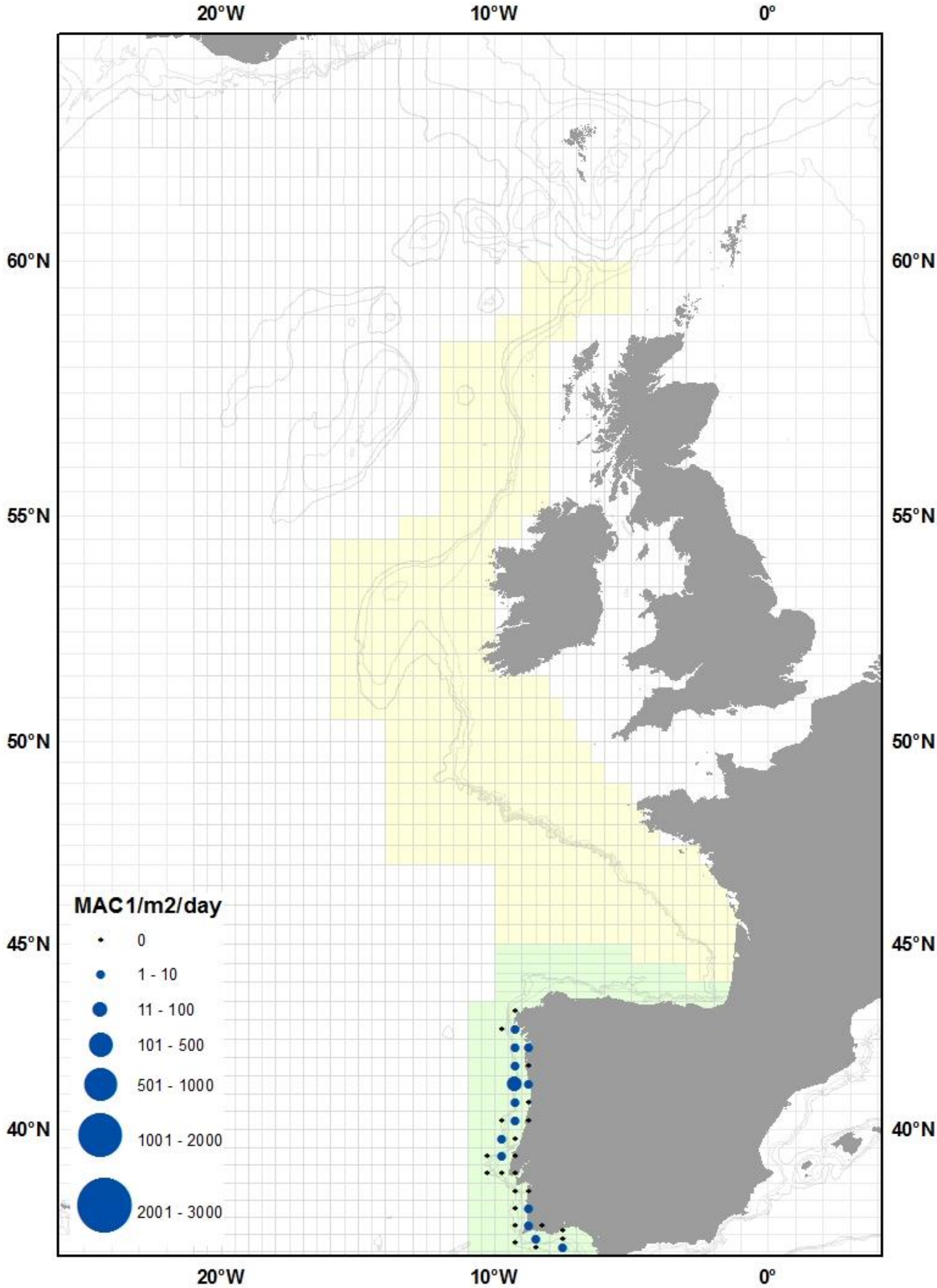


Figure 2: Mackerel egg production by half rectangle for period 2 (19th February – 27th March). Filled blue circles represent observed values, filled red circles represent interpolated values, black crosses represent observed zeroes, red crosses interpolated zeroes.

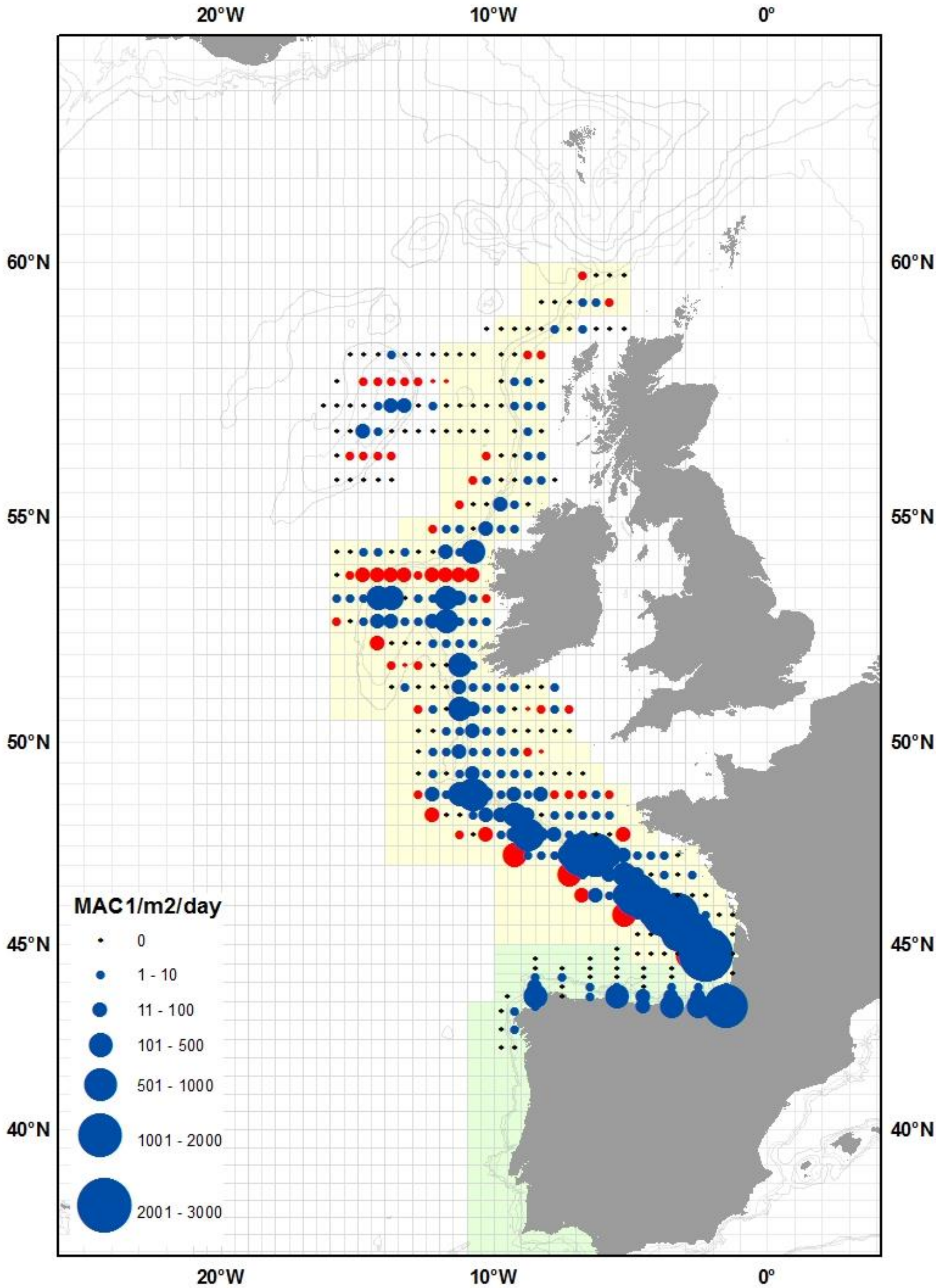


Figure 3: Mackerel egg production by half rectangle for period 3 (28th March – 6th May). Filled blue circles represent observed values, filled red circles represent interpolated values, black crosses represent observed zeroes, red crosses interpolated zeroes.

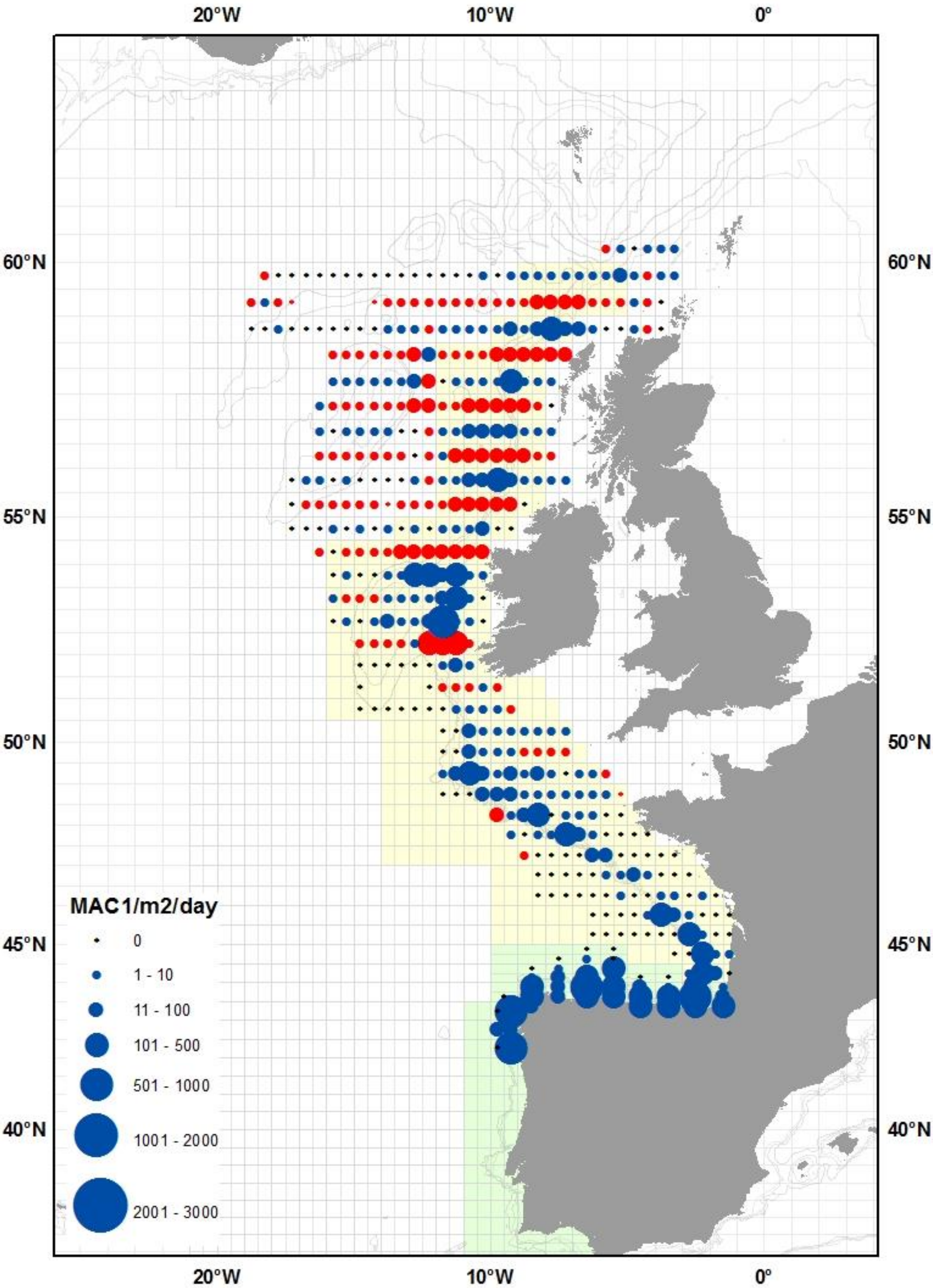


Figure 4: Mackerel egg production by half rectangle for period 4 (7th May – 3rd June). Filled blue circles represent observed values, filled red circles represent interpolated values, black crosses represent observed zeroes, red crosses interpolated zeroes.

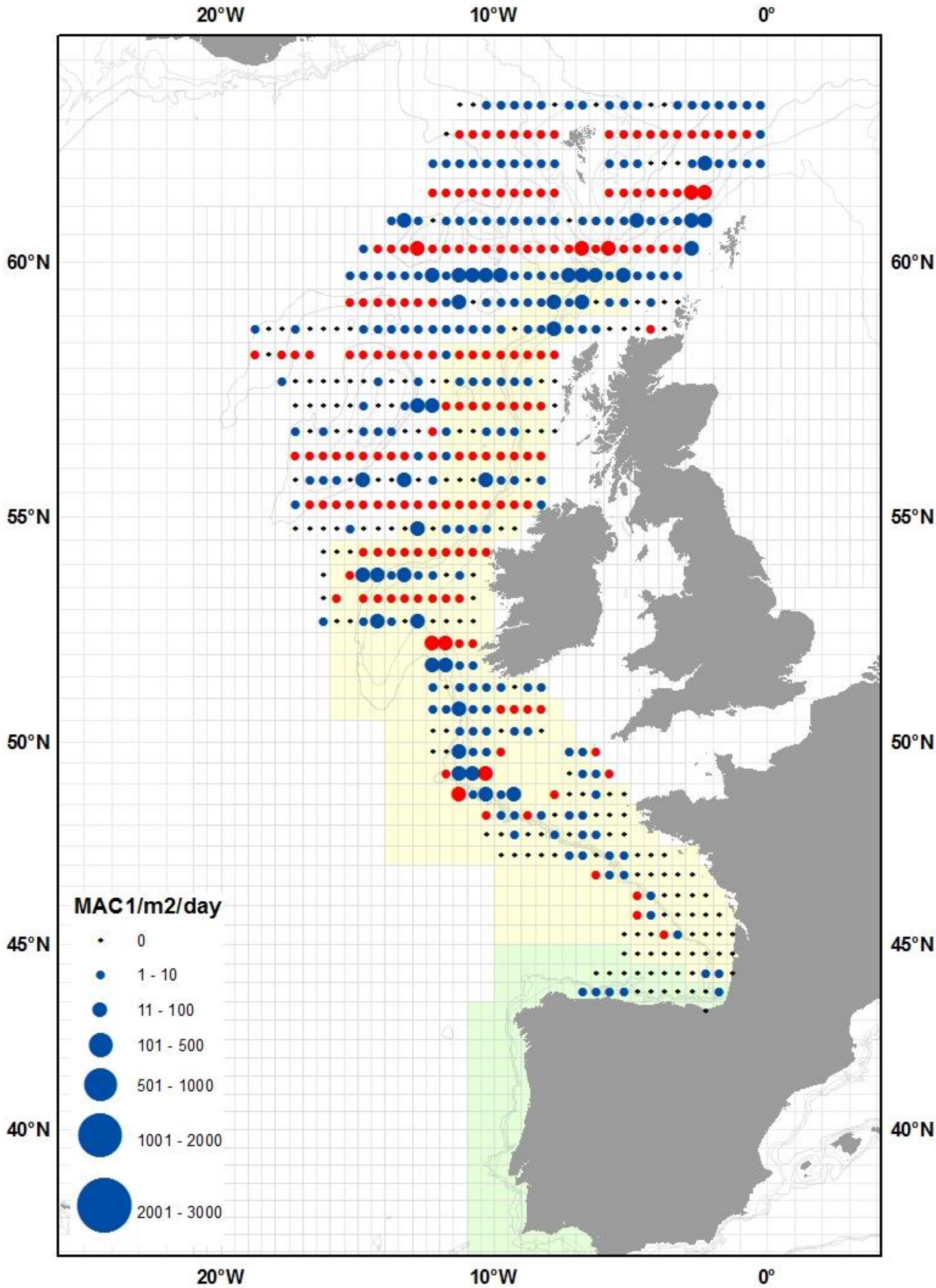


Figure 5: Mackerel egg production by half rectangle for period 5 (4^{th} June – 26^{th} June). Filled blue circles represent observed values, filled red circles represent interpolated values, black crosses represent observed zeroes, red crosses interpolated zeroes.

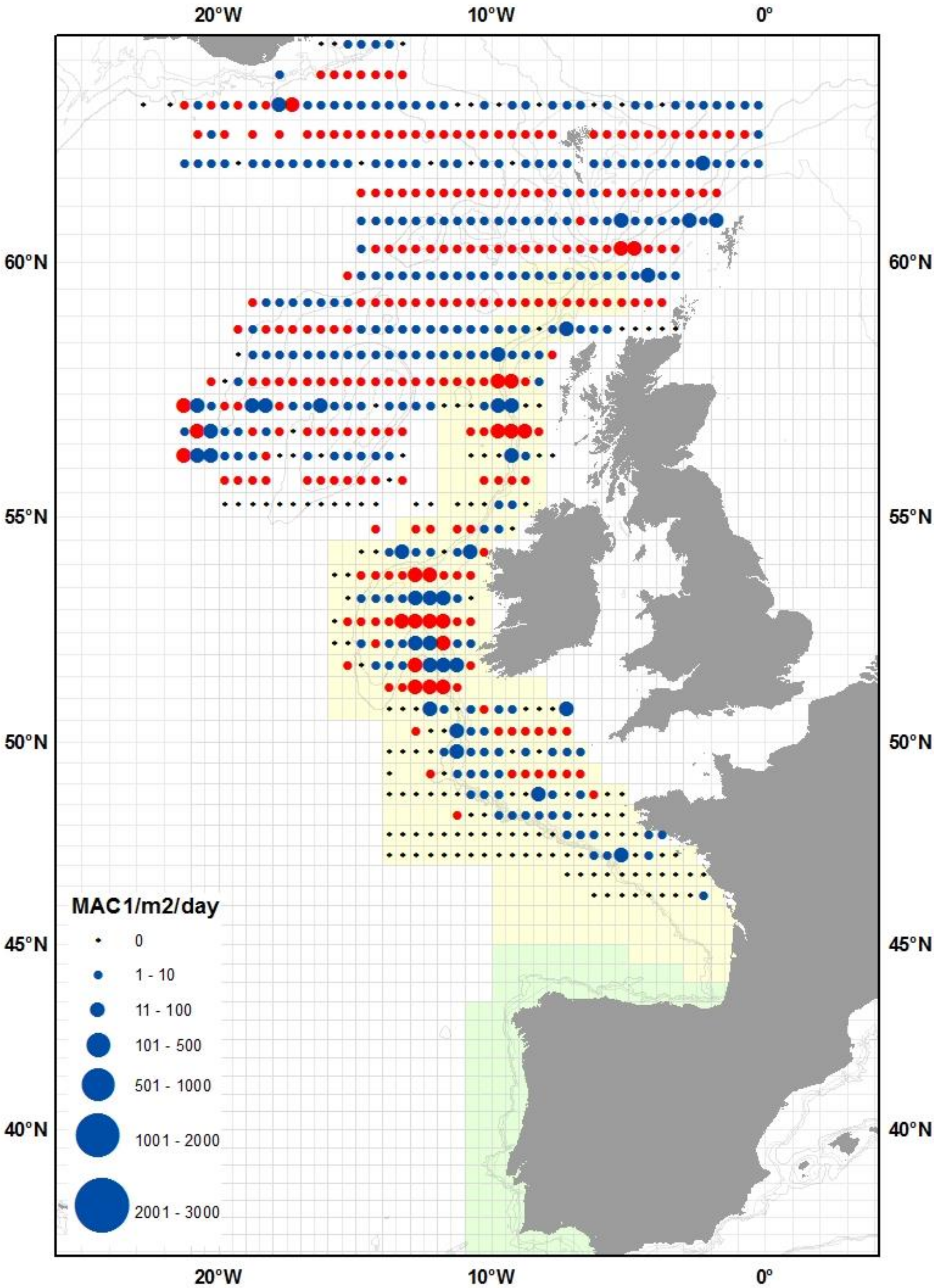


Figure 6: Mackerel egg production by half rectangle for period 6 (15th July – 31st July). Filled blue circles represent observed values, filled red circles represent interpolated values, black crosses represent observed zeroes, red crosses interpolated zeroes.

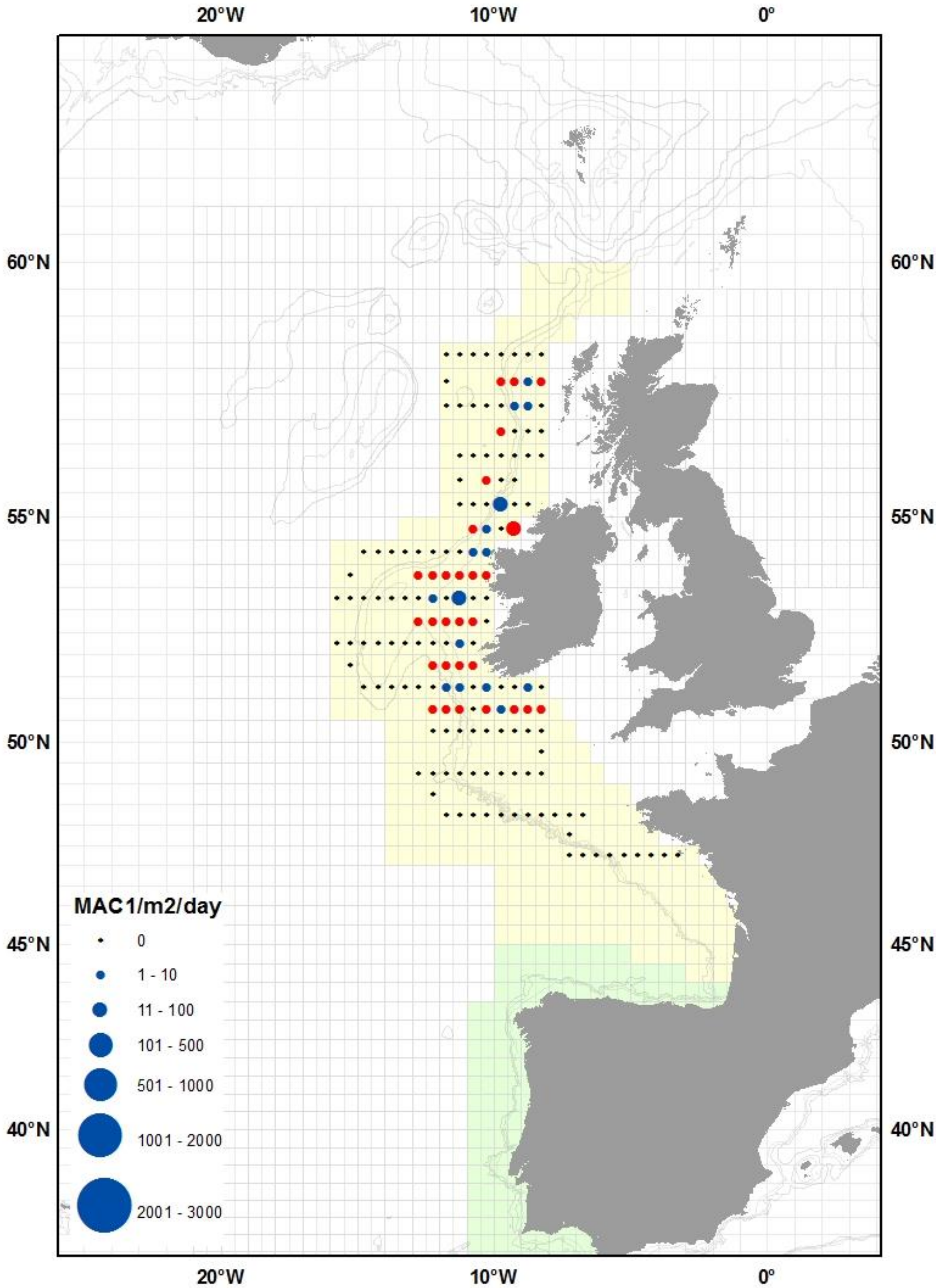


Figure 7: Horse mackerel egg production by half rectangle for period 2 (19th February – 27 th March). Filled green circles represent observed values, filled red circles represent interpolated values, black crosses represent observed zeroes, red crosses interpolated zeroes.

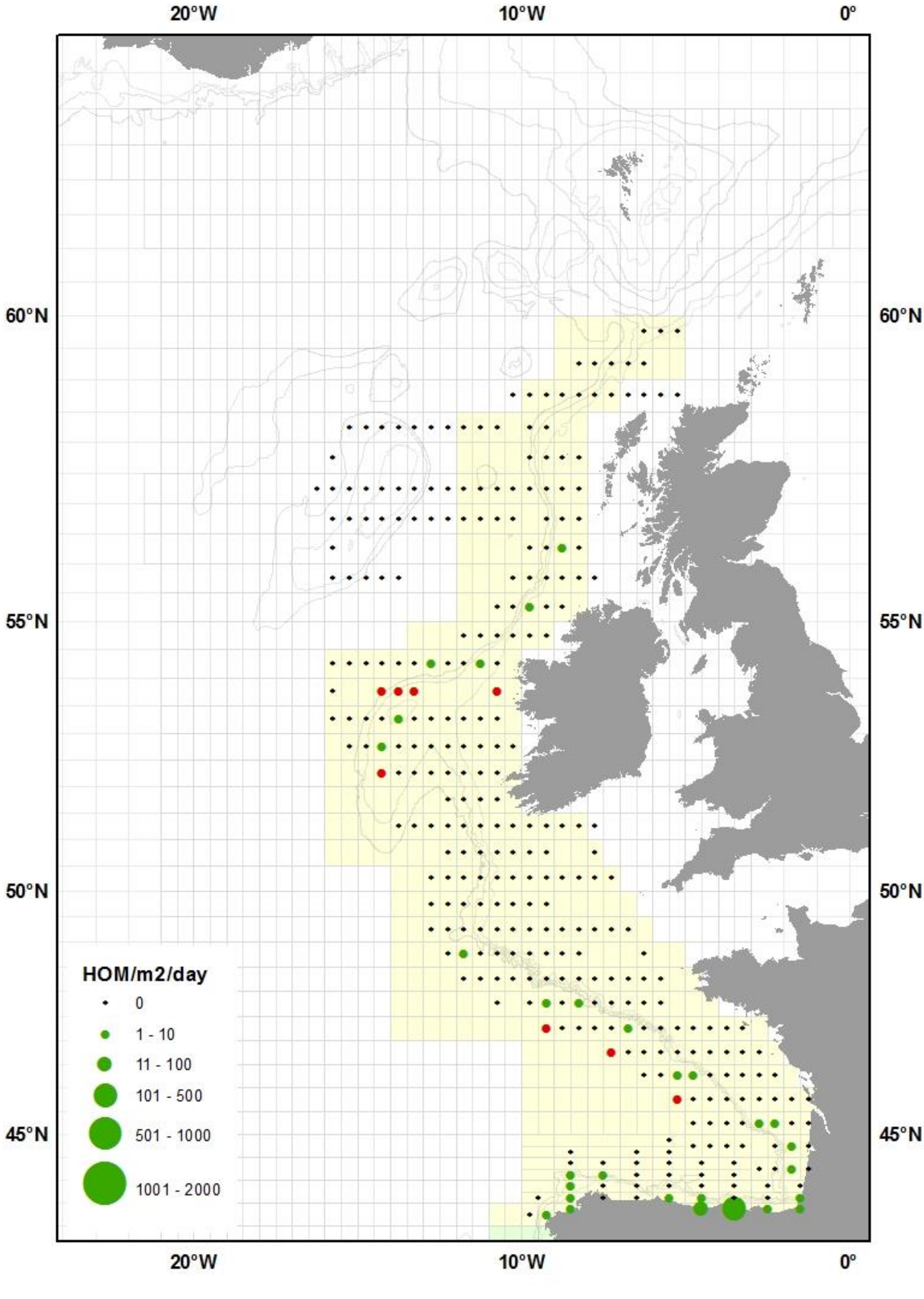


Figure 8: Horse mackerel egg production by half rectangle for period 3 (28th March – 6th May). Filled green circles represent observed values, filled red circles represent interpolated values, black crosses represent observed zeroes, red crosses interpolated zeroes.

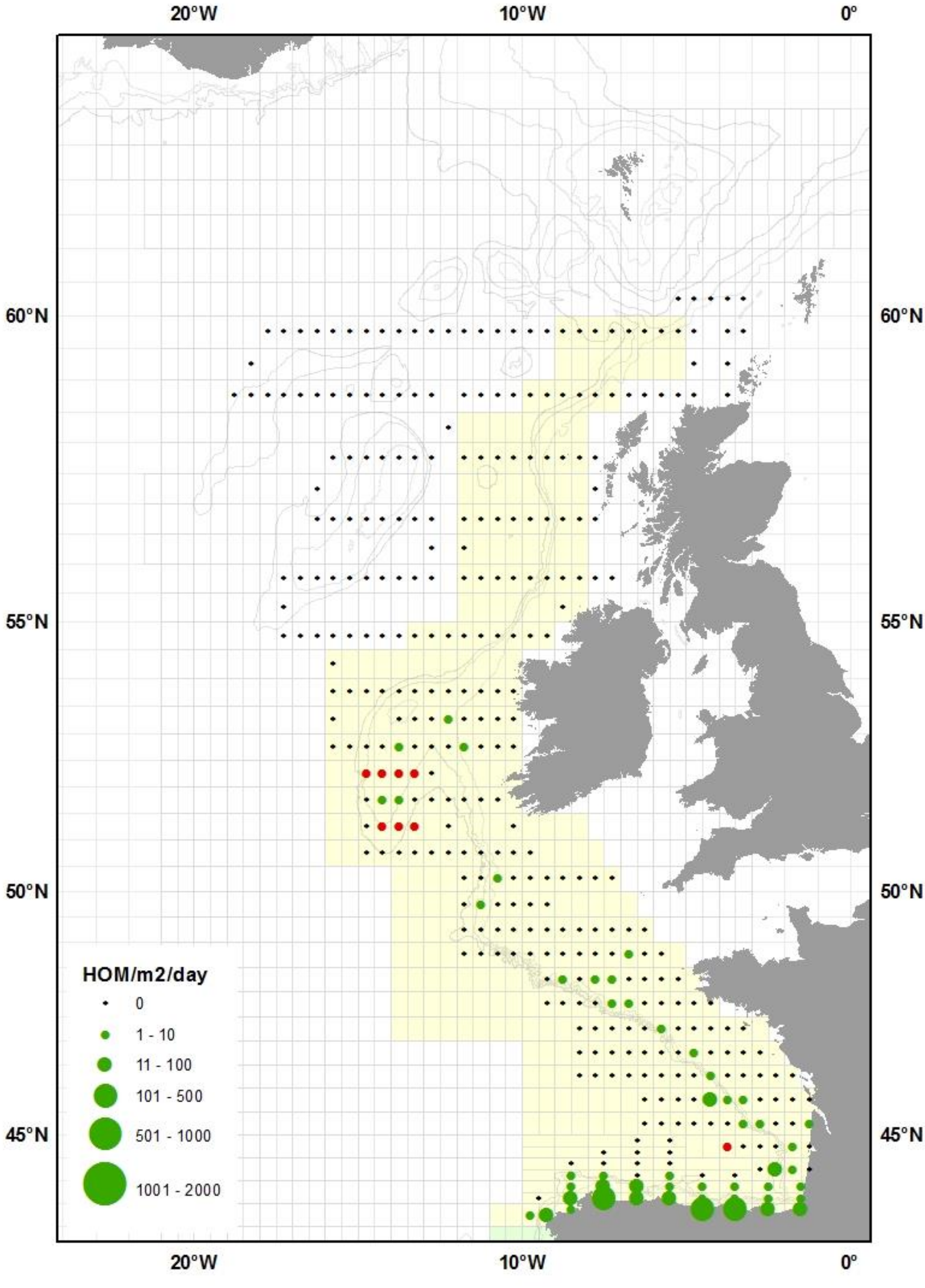


Figure 9: Horse mackerel egg production by half rectangle for period 4 (7th May – 3rd June). Filled green circles represent observed values, filled red circles represent interpolated values, black crosses represent observed zeroes, red crosses interpolated zeroes.

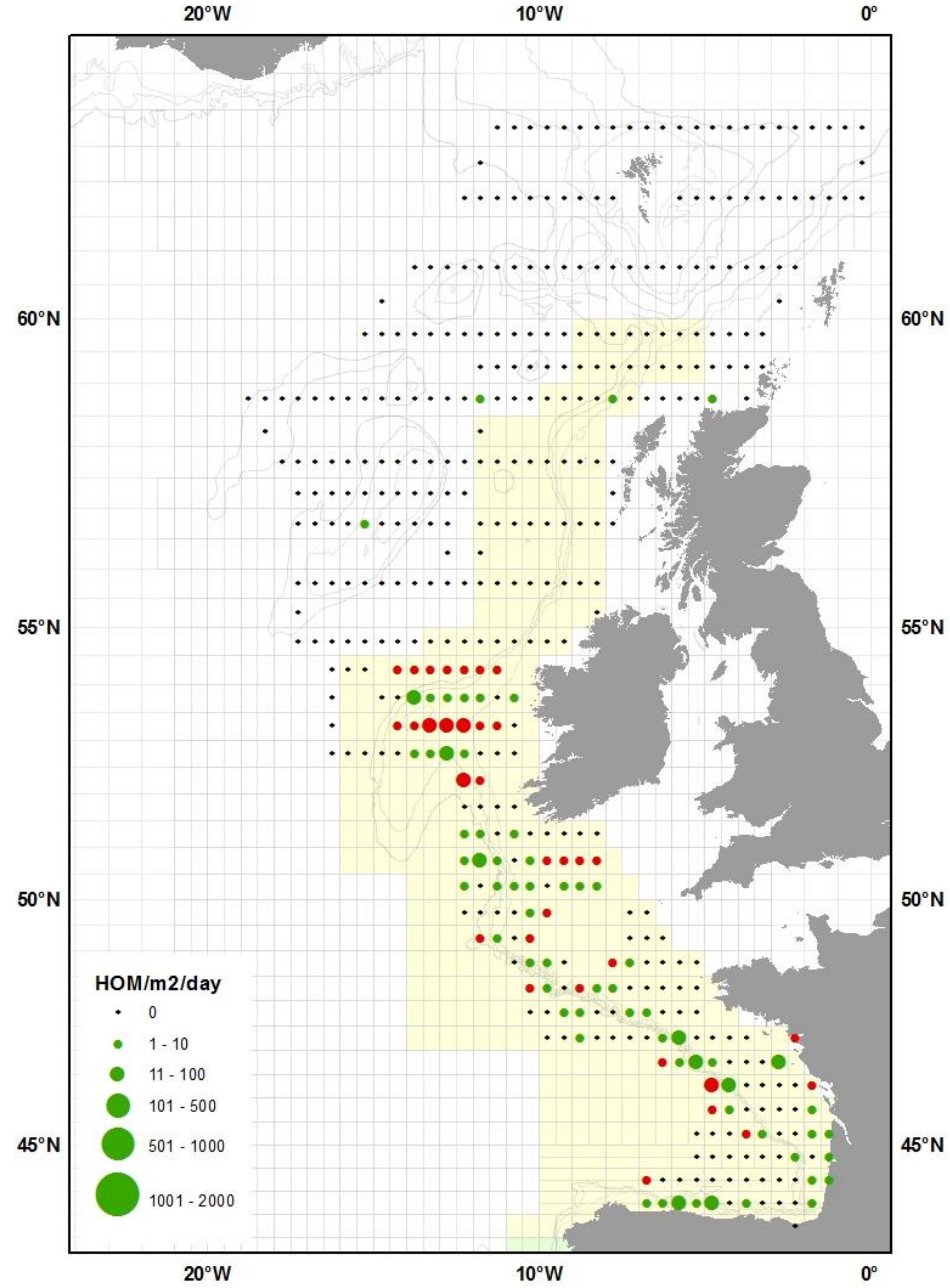


Figure 10: Horse mackerel egg production by half rectangle for period 5 (4th June – 26th June). Filled green circles represent observed values, filled red circles represent interpolated values, black crosses represent observed zeroes, red crosses interpolated zeroes.

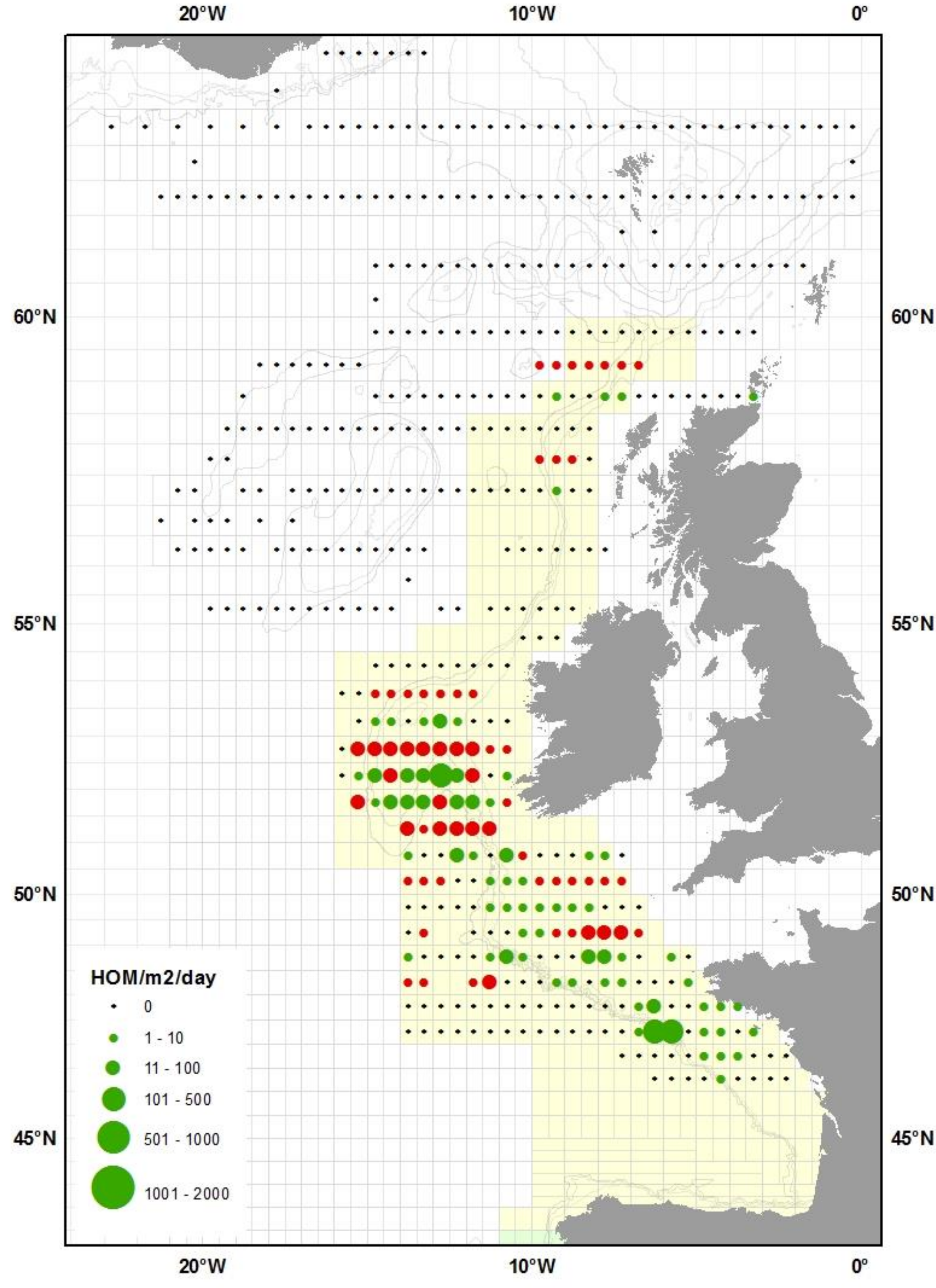
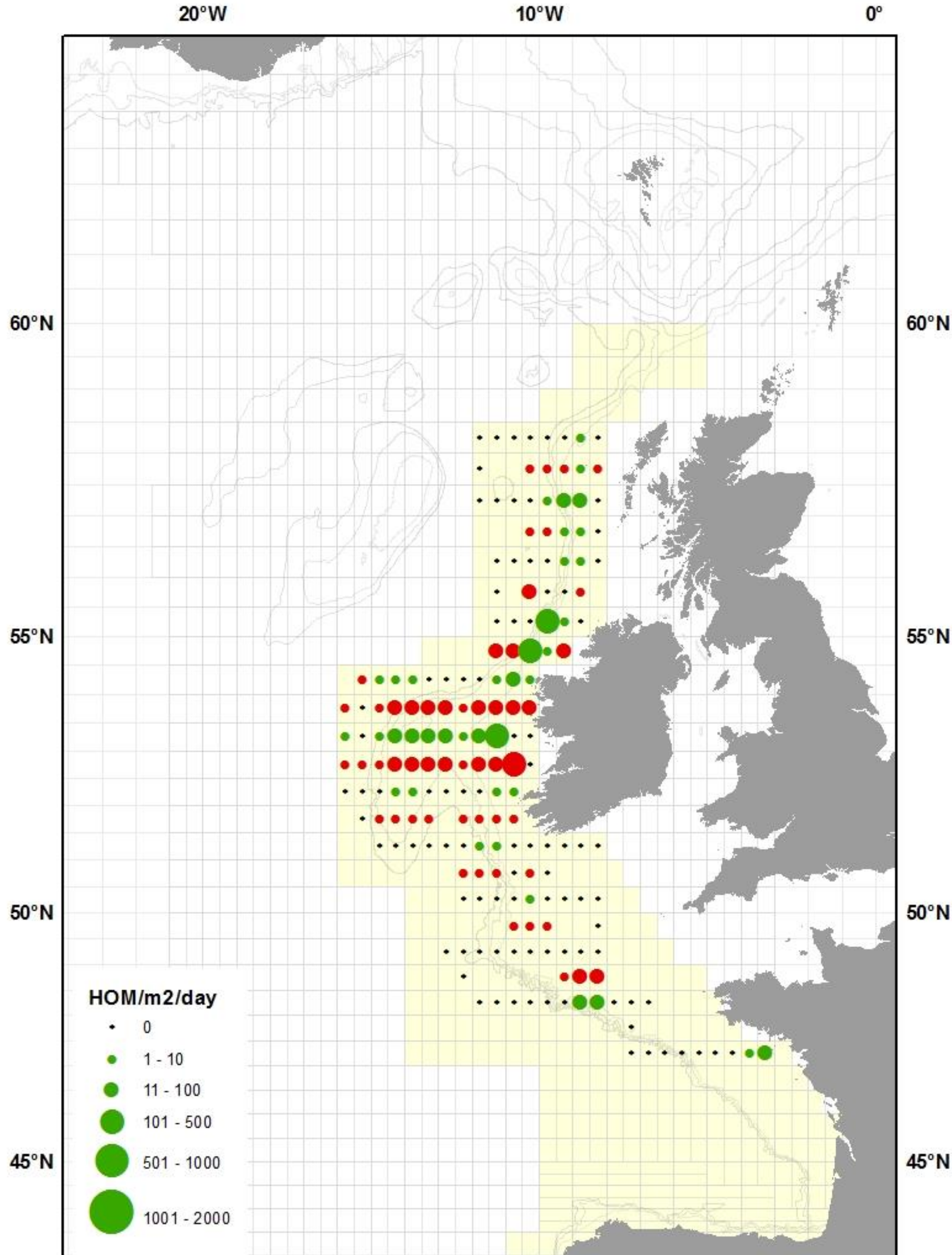


Figure 11: Horse mackerel egg production by half rectangle for period 6 (15th July – 31st July). Filled green circles represent observed values, filled red circles represent interpolated values, black crosses represent observed zeroes, red crosses interpolated zeroes.



Working document
WGWIDE 2013

Exploring the assessment with TASACS

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Including this years data in a SPALY assessment with TASACS led to changes in the perception of the state of the stock, some of which were surprising and out of proportion with the added information. On request from IMR, I have examined possible causes and made some suggestions for how to handle the problems.

1. There is a strong retrospective trend that has appeared for several years and still continues. The trend is to adjust the biomass in recent years downwards, shown in Figure 1.

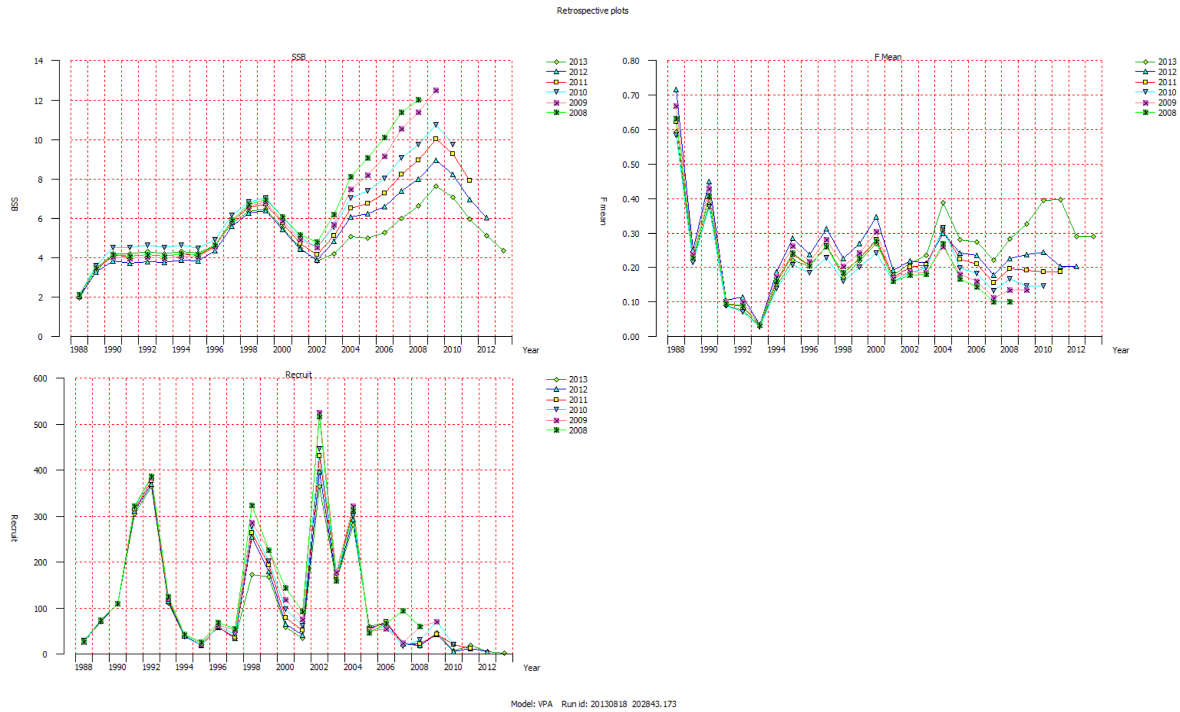

Figure 1. *Retrospective plot.*

2. The magnitude of some year classes changed from the 2012 assessment, sometimes quite drastically. This is illustrated in the figures 2-4 below, showing the year classes at terminal stage and as back-calculated to recruitments. In particular, the 1998 year class is reduced, but also the 1999 and 1983. The 1985 year class is increased at old age, but due to small catches over the years it is still small as recruits.

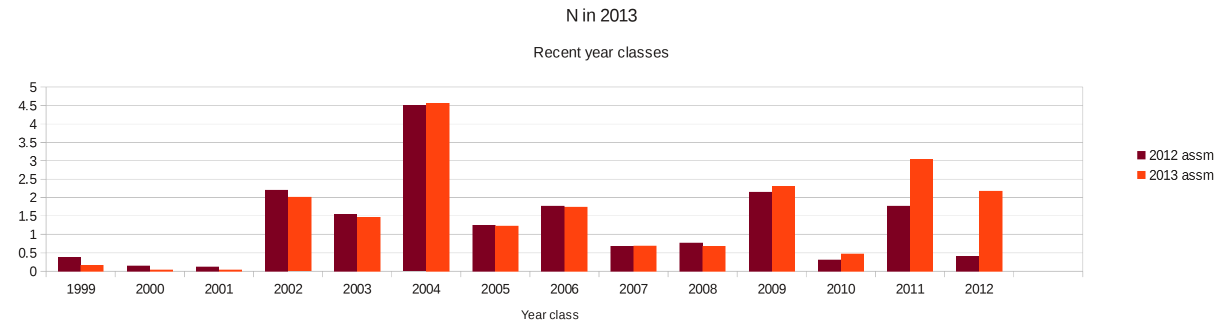

Figure 2. *Change in estimates of N-values in 2013 from 2012 to 2013 assessment for year classes that are still present in the final year.*

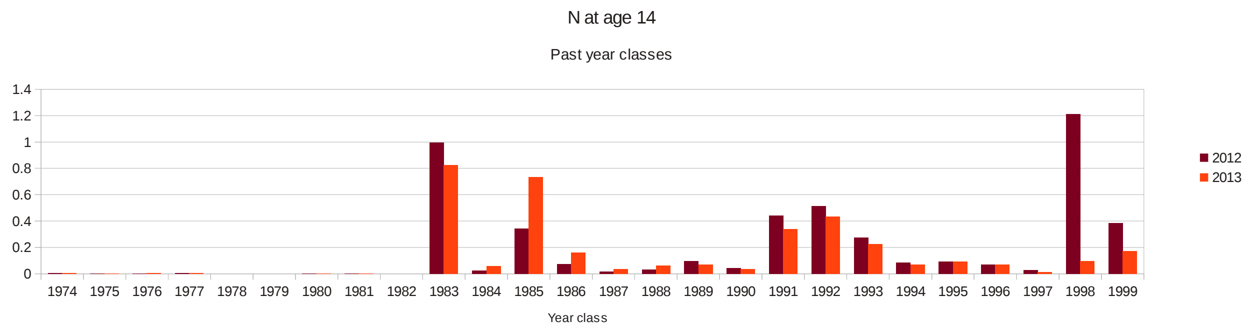

Figure 3. *Change in estimates of N-values at age 14 from 2012 to 2013 assessment, for year classes that have past the oldest true age of 14 years.*

Figure 4. *Change in estimates of year class strength (N-values back calculated to age 1) from 2012 to 2013 assessment, for all year classes.*

3. The catchability of survey fleets changed, sometimes drastically. This is shown for each of the tuning fleets in Figure 5 below.

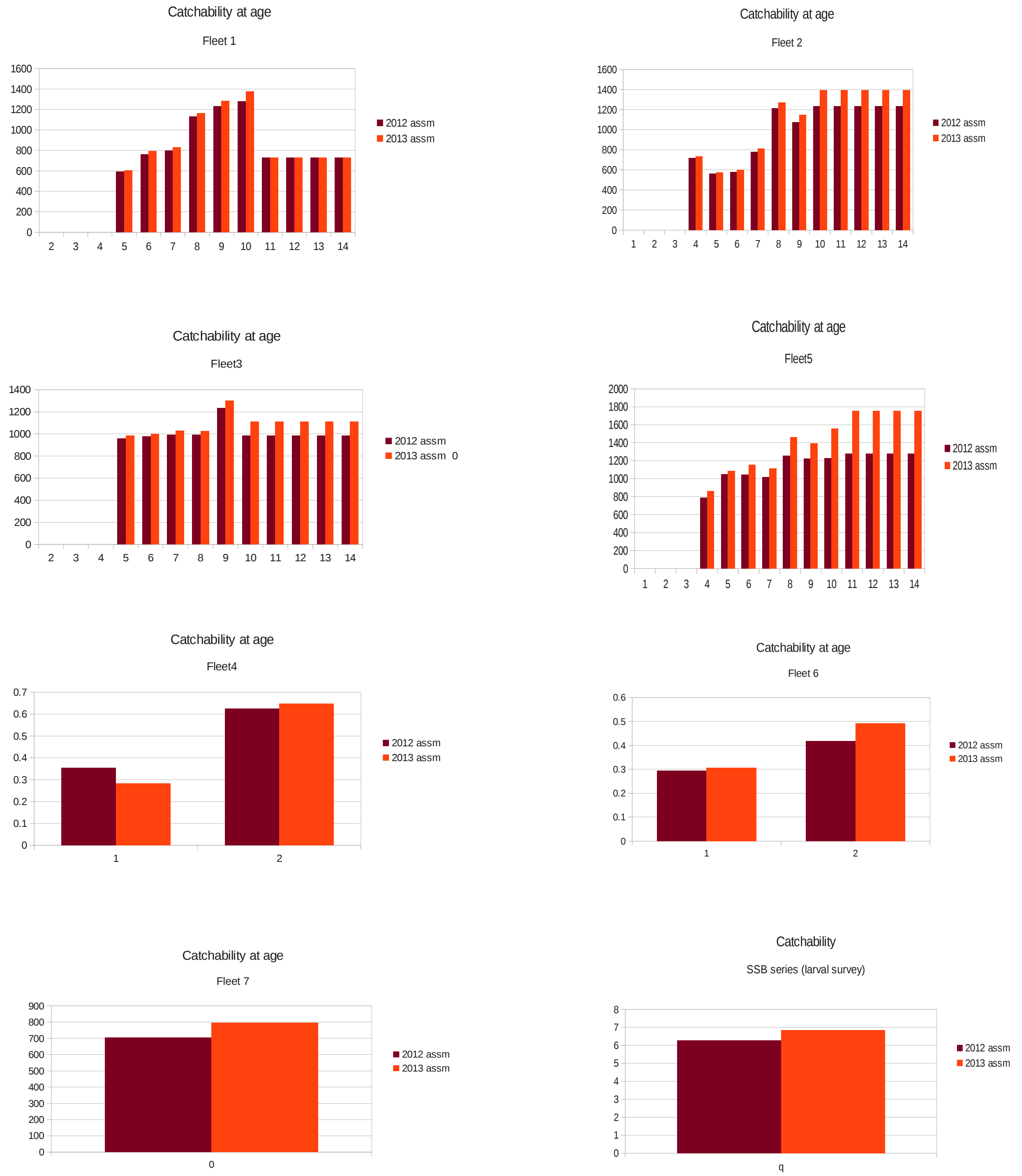

Figure 5 *Catchabilities by tuning fleet estimated in the 2012 and 2013 assessments*

The cause of these changes is not quite obvious, and there may be multiple causes.

The retrospective inconsistency can have several reasons, but one common one is that it is caused by the protracted influence of year effects in surveys. For example, a too high survey index in one year will lead to a high estimate of the stock in that year. In the following years, it will still want to pull the year classes upwards, but gradually less so as more information about the year classes is assembled. At that stage, the year effect will appear as positive residuals.

The residuals for fleet 5 (Figure 6) have a quite strong cluster of negative residuals from 2001 to 2005 and positive residuals from 2006 to 2009, in particular for the older ages. Such clusters can be expected to lead to retrospective inconsistency.

Figure 6. *Residuals Fleet 5 in 2013 assessment*

The change in catchability for fleet 5 is more puzzling. With a year effect as in fleet 5, one might expect an increased catchability to accomodate the high values in the past, but not this drastic change from one year to the next.

The change in the abundance estimate of some year classes, in particular the 1998 year class, could be part of that picture, but the mechanism could also be more complex. To explore that, a run was made with the 2013 data where just the 1998 year class was forced to have a higher value at age 14, in line with what was seen in the 2012 assessment - referred to as the 'High' option in the following. This defines the time course of that year class uniquely since this is a VPA.

Figure 7 show the results of fixing the survivor number for the 1998 year class. Included in the figure is also runs where the SSB tuning series was excluded, to be discussed later. The fit to the data with the 'High' option was poorer, and it turned out that this was because of a much poorer fit to the SSB tuning series (the larval survey), while the fit to fleet 5 was slightly better (compare the options Org (standard setup) with the option High).

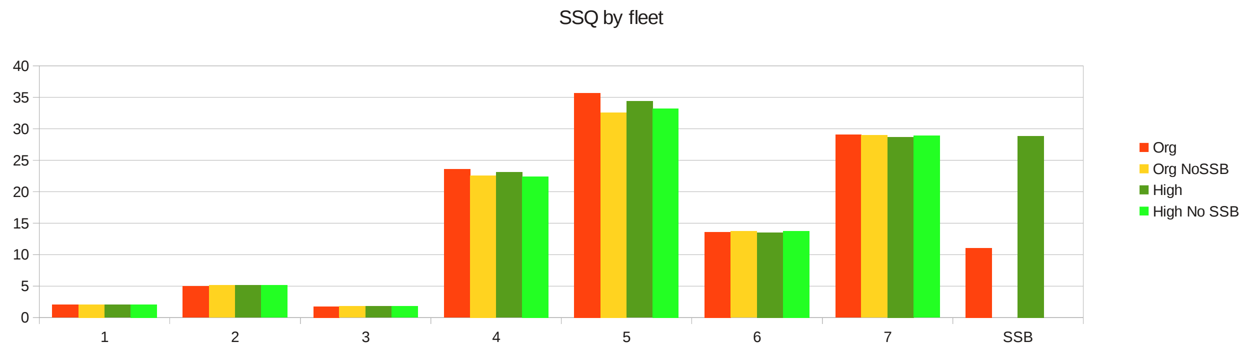

Figure 7. *Fit (SSQ) to each tuning fleet in the original 2013 assessment and when fixing the survivor number for the 1998 year class to a higher number (High option), with and without including the SSB tuning series in the analysis.*

The reason for this poorer fit with the "High' option was that the SSB estimates in the past were lifted while those in the recent period were reduced (Figure 8). This pattern did not appear in the 2012 assessment.

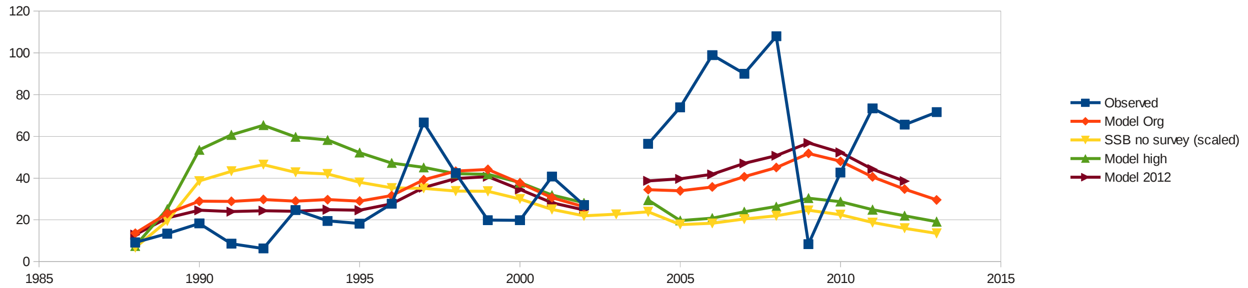

Figure 8. *Modelled (Catchability times estimated SSB) and observed values for the SSB survey in the original 2013 assessment and when fixing the survivor number for the 1998 year class to a higher number (High option). The yellow curve is the estimated SSB when the SSB survey was not included, scaled arbitrarily. The modelled values from the 2012 assessments are also included.*

This effect was quite surprising, and difficult to trace.

The SSB series is problematic in itself, because the observed values vary over a wide range while the modelled SSB by all standards are at almost the same level (Figure 9).

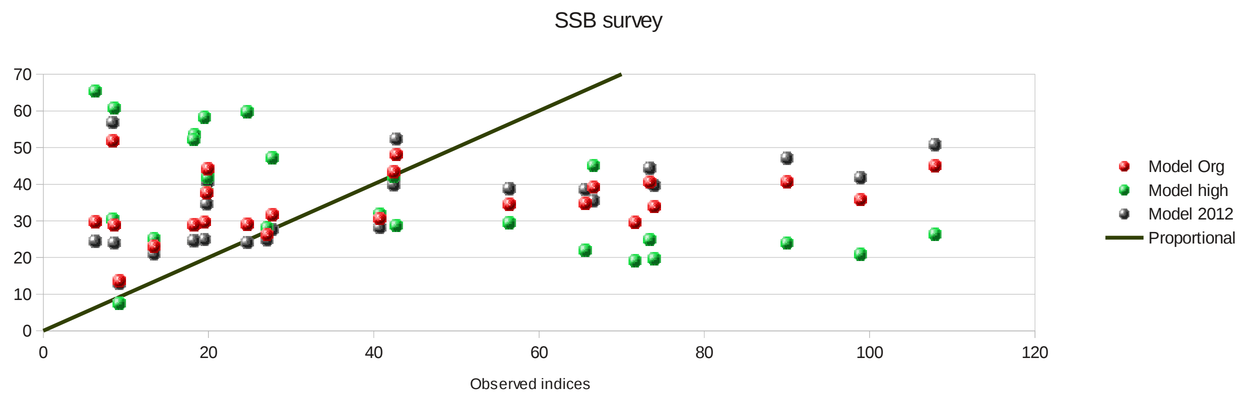

Figure 9. *Modelled values of the SSB survey vs. the observed values. The line is the diagonal.*

Hence, first of all an attempt was made to just remove this survey from the analysis. This led to estimates of the stock and model fit largely in line with the High option (Figures 7 and 8). Note that the SSB with the no survey option is scaled arbitrarily in the figure. Clearly, the strange pattern in historic SSB estimates is not caused just by the poor fit to the SSB data series, even if this fit determines the final value of the N14 for the 1998 year class.

The open question then is how a small adjustment in a stock number in 2013 can have this big influence on the perception of the past history. Clearly, it is not just a question of adjusting some recent year classes as new data are added about them, there must be secondary or tertiary effects to such adjustments. One candidate explanation could be that changes in catchabilities lead to a different perception of older year classes. However, these older year classes have terminal Ns that get fixed without using the survey data, and thus are fixed all the way by the terminal Ns and the catches. Therefore, the change in catchability must be secondary to changing these year classes rather than the other way around.

Accordingly, the place to investigate further is how terminal Ns are fixed in year classes that are not fitted to survey data. There are two options for that in TASACS:

1. The terminal N can be fixed manually (Flag 0 in TASACS)
2. Flag 3 in TASACS: The terminal N can be derived from a terminal F that is obtained as:

   *TermF(y) = TermF(y+1)*averageF(y)/averageF(y+1)*

   where the average F is taken over the reference ages (5-14 for herring), but excluding ages where the F is undefined or the F is zero. If such ages are excluded, it is done for both the years.

In the current assessment, the Flag 0 option is applied for the very small year classes 2000 and 2001. The Flag 3 option is used for the year classes 1989 and older, except for the 1983 year class, which is fitted to the data. Correspondingly, the Flag 3 option is applied to the oldest true age (age 14) in the years 2002 and earlier, except in 1997 (the 1983 year class).

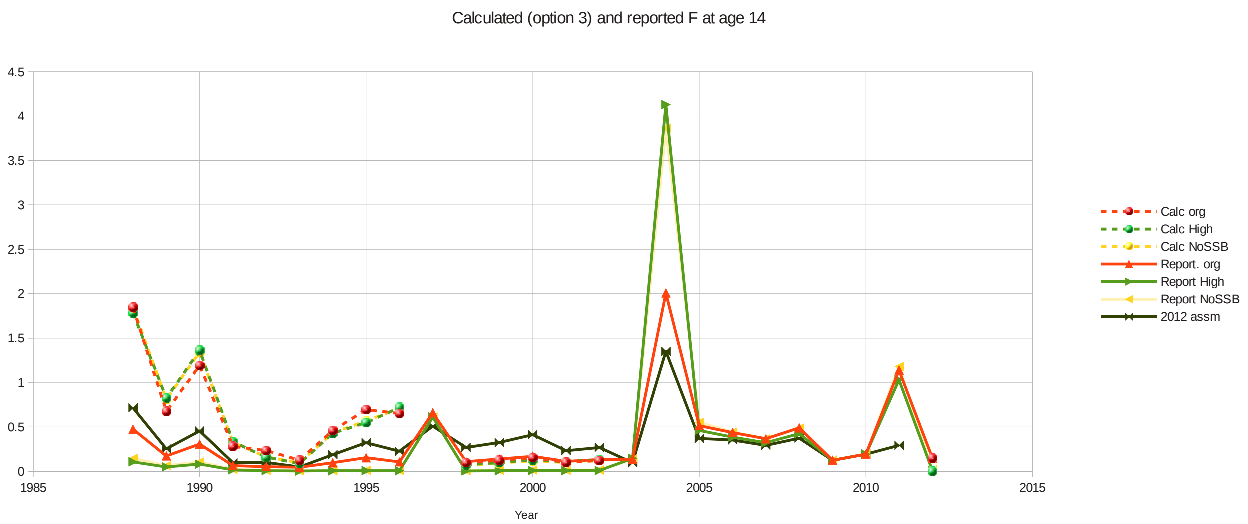

Figure 10. *Fishing mortality at age 14 as tabulated in the summary file in the SPALY run ('Report org'), with a high terminal N for the 1998 year class ('Report High', and the SPALY run without including the SSB tuning series ('Report NoSSB') - largely overlapping the 'High' curves). Hatched lines are obtained by applying the formula for the Flag 3 option to the tabulated F-values. The tabulated values in the 2012 assessment are also included.*

Figure 10 shows that in some years, the terminal Fs behave strangely:

- 2011, 2004 and 1997 all have an unusually high F at age 14. All these are estimated with tuning data.
- The derived Fs do not behave as expected, and both periods with derived Fs are triggered by 'unusual' Fs.
- The Fs before 1997 are now much lower than those in the 2012 assessment

The exact explanation for this still remains to be clarified, also if there is a mistake in the present analysis or a bug in TASACS.

Suggestions: Irrespective of possible bugs in deriving terminal stock numbers, it appears that the algorithm used at present makes the TASACS assessment unstable, with a great sensitivity to small changes in recent stock abundances. Obviously, this is not satisfactory. Likewise, the retrospective pattern is not satisfactory. One may think of several solutions to these problems:

1. Accounting for the apparent year effect in survey 5 by estimating a separate catchability for the period 2006-2009. TASACS does not allow setting the catchability in 2010 onwards equal to that before 2006, which should be desirable, but it can be done manually. Alternatively, one could estimate it for 2010-2013, and fix those values if a retrospective run is wanted. This is just a 'quick fix', however.
2. Removing the SSB survey might seem justified, but it does not solve the problem.
3. Apply an improved algorithm for the oldest age when there is no tuning data. The present algorithm picks up noise in the tuned estimates and carries them backwards, and it is not clear if there is bugs somewhere in that algorithm.

Regarding pt. 3, an alternative would be to have a fixed ratio between F at oldest age and average F in the year, which is equivalent to assuming a fixed selection at oldest age. This is equivalent to the way it is done in ICA, and in the separable option in TASACS. This is included as an additional option in TASACS now. The program will take the ratio from the selection parameters, as the selection at oldest age relative to the mean over the mean over the reference ages.

There is no standard way to estimate that ratio. It may be derived by taking the ratio between mean Fs at age 14 vs. mean reference F over the years where it is estimated, which would give a ratio around 1.7.It should be noted that the experience from ICA, where this ratio is set manually, is that the history can be quite sensitive to the choice of ratio, so this solution is not ideal, but may give some realism in the choice.

Using the option to link F at oldest age to the mean F in the year by a fixed ratio took away the instabilities and inconsistencies that were discussed above. In particular, if N14 for the 1998 year class was altered, it the influence was restricted to that year class, with only minor changes in other year classes. However, it did not remove the retrospective error.

When in addition, the catchability in the period 2006 - 2009 was estimated separately, the retrospective error disappeared in the last few years, but remained when the last year was 2009 and earlier, as might be expected. To treat the period 2006-2009 separately, the *ad hoc* solution was to fix the catchabilities for 2010 onwards manually to the values before 2006. This took a few iterations.

The results, and the retrospective pattern with these amendments is shown in Figure 11 below.

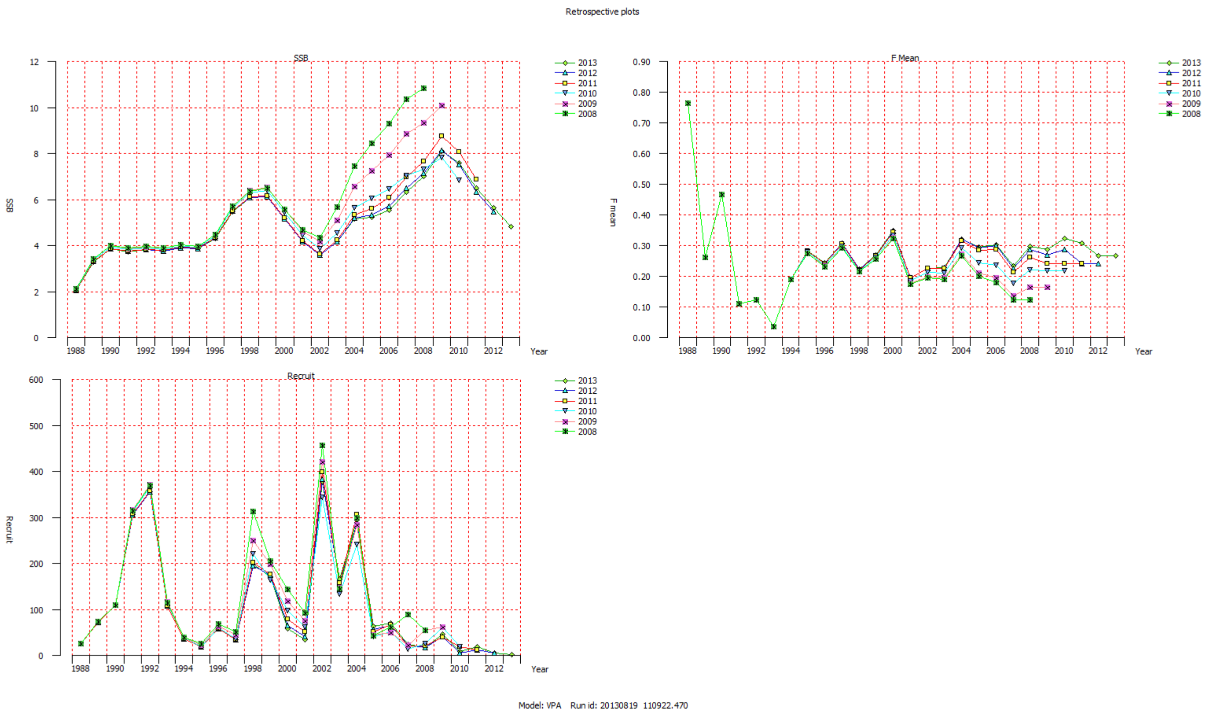

Figure 11. Retrospective pattern with the suggested changes to the TASACS assessment.

Alternatively, one could reconsider using the separable option in TASACS. This was seriously considered when TSACS was adopted as standard assessment. The difference at the time was small, and the choice was almost, but not quite arbitrary. This option has not been properly tested now.

Another option that has been discussed previously is to reduce the plus age from 15 to 11. This was tried only briefly, but does not seem to solve the present problems. The data at old age are noisy, however, and there may be drifting between year classes due to difficulties in age reading. Therefore, reducing the plus age should still be on the agenda.

Conclusion
In order not to make more changes than necessary, it is suggested to apply the proposed new algorithm for deriving N-values at the oldest true age when no supporting information can be used, and in addition to calculate the catchability for fleet 5 in 2006-2009 separately, as described above. The justification for the first measure is to eliminate a very unsatisfactory instability in the estimates of starting values for the cohorts, and for the second to reduce the protracted impact of an identified source of retrospective error.

Update on the discards of WGWIDE species by the Portuguese bottom otter trawl fleet operating in the Portuguese ICES Division IXa

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Abstract

We compiled the information available on the discards of WGWIDE stocks produced by Portuguese vessels operating with bottom otter trawl in Portuguese ICES Division IXa. The data was collected by the Portuguese on-board sampling programme (EU DCR/NP) between 2004 and 2012. The fisheries analysed were the bottom otter trawl fishery targeting crustaceans (OTB_CRU) and the bottom otter trawl fishery targeting demersal fish (OTB_DEF). The species analysed were boarfish (*Capros aper*), Atlantic herring (*Clupea harengus*), Atlantic mackerel (*Scomber scombrus*), chub mackerel (*Scomber colias*) and blue whiting (*Micromesistius poutassou*). Fleet level estimates of discards volume, length composition, and age distribution are provided for the year × fishery × species combinations where discards were more frequently observed. Herring was not caught in any of the trips observed onboard during this period.

1 Introduction

This working document compiles the information available on the discards of WGWIDE stocks produced by the Portuguese bottom otter trawl fisheries in Portuguese ICES Division IXa. The data was collected by the Portuguese on-board sampling programme (EU DCR/NP) between 2004 and 2012. The fisheries analysed were the bottom otter trawl fishery targeting crustaceans (OTB_CRU) and the bottom otter trawl fishery targeting demersal fish (OTB_DEF). The species analysed were boarfish (*Capros aper*), Atlantic herring (*Clupea harengus*), Atlantic mackerel (*Scomber scombrus*), chub mackerel (*Scomber colias*) and blue whiting (*Micromesistius poutassou*). The document starts with a description of the on-board sampling programme and details of the estimation algorithms and data quality assurance procedures (Section 2). Then, results on the annual frequencies of occurrence, numbers sampled, and length composition of individuals sampled in discards of the different taxa are presented. Finally, fleet-level estimates of discard volume, length composition and age structure are presented for the year × fishery × species combinations where discards were more frequently observed (Section 3).

2 Onboard sampling and data analysis

2.1 Trip selection

Please refer to Prista et al. (2012).

2.2 Catch sampling

Please refer to Prista et al. (2012).

2.3 Estimates of discards (haul and set level)

Please refer to Prista et al. (2012).

2.4 Estimates of discards (fleet level)

Please refer to Prista et al. (2012). No 35 cm individuals were registered in the 2012 ALK for blue whiting but this length class was found in the discards sampled in 2012. In this case, the age distribution of the length class 35 cm ALK in 2011 was used.

2.5 Quality assurance procedures

Please refer to Prista et al. (2012) but note that the 2004-2011 logbook data supplied by the Portuguese Directorate-General for Natural Resources, Security and Maritime Services (DGRM) used to raise onboard data to fleet level was based on paper logbooks. However, in 2012 DGRM discontinued most of its logging of paper logbooks as it adapted its database to electronic logbooks. At the time of the present report, 2012 effort data from electronic logbooks was not available so this year's results at fleet-level were raised using available (but incomplete) paper logbook information. Consequently, 2012 discard estimates at fleet level should be considered provisional. Data used in the current estimates were extracted from the IPMA database in 21/06/2013. The DGRM data used in the current discard estimates was compiled in 6-18/03/2012.

2.6 Species identification

Please refer to Prista et al. (2012).

3 Species discards

3.1 Sampling levels

Sampling levels attained by the Portuguese onboard sampling programme on the bottom otter trawl fisheries (OTB) are presented in Table 1.

Table 1: Sampling levels achieved by the Portuguese onboard sampling programme in the two OTB fisheries: bottom otter trawl targeting crustaceans (OTB_CRU) and bottom otter trawl targeting demersal fish (OTB_DEF) (2004-2012).

	Trips sampled		Hauls sampled		Hours fished	
Year	OTB_CRU	OTB_DEF	OTB_CRU	OTB_DEF	OTB_CRU	OTB_DEF
2004	17	24	111	125	479	315
2005	15	39	74	159	372	349
2006	7	42	30	194	133	380
2007	12	38	73	162	263	296
2008	12	34	66	128	267	254
2009	16	38	84	135	314	264
2010	16	31	103	116	375	208
2011	13	30	56	83	217	161
2012	13	31	68	60	302	130

3.2 Selected species

Species codes and common names used in the present report are displayed in Table 2.

Table 2: Species codes and common names

3-alpha code	Species	Common name (EN)	Common name (PT)
BOC	*Capros aper*	Boarfish	Mini-saia
HER	*Clupea harengus*	Atlantic herring	Arenque
MAC	*Scomber scombrus*	Atlantic mackerel	Sarda
MAS	*Scomber colias*	Chub mackerel	Cavala
WHB	*Micromesistius poutassou*	Blue whiting	Verdinho

3.3 Frequency of occurrence

The annual frequencies of occurrence of WGWIDE species in discards of the Portuguese OTB fisheries are displayed in Table 3 and Table 4. The number of individuals sampled in each year is displayed in Table 5 and Table 6.

Table 3: Frequency of occurrence (%) of WGWIDE species in the discards of the hauls sampled onboard the Portuguese OTB_CRU fishery (2004-2012). See Table 2 for species codes; "—" indicates no occurrence; "bold" numbers indicates frequency of occurrence $\geq$30%

YEAR	BOC	HER	MAC	MAS	WHB
2004	**32**	0	10	9	**83**
2005	16	0	11	7	**86**
2006	**47**	0	10	17	**77**
2007	**36**	0	22	19	**70**
2008	17	0	18	**35**	**56**
2009	**57**	0	1	7	**68**
2010	29	0	4	**31**	**84**
2011	**39**	0	25	**30**	**91**
2012	**32**	0	22	12	**72**

Table 4: Frequency of occurrence (%) of WGWIDE species in the discards of the hauls sampled onboard the Portuguese OTB_DEF fishery (2004-2012). See Table 2 for species codes; "bold" numbers indicates frequency of occurrence ≥30%

YEAR	BOC	HER	MAC	MAS	WHB
2004	**33**	0	23	**38**	**46**
2005	26	0	18	**36**	26
2006	**52**	0	17	**45**	**35**
2007	**46**	0	**32**	**69**	26
2008	**42**	0	20	**75**	15
2009	**48**	0	23	**70**	19
2010	27	0	22	**67**	**37**
2011	25	0	29	**71**	18
2012	**47**	0	**37**	23	**33**

Table 5: Number of individuals from WGWIDE species sampled in the discards of the Portuguese OTB_CRU fishery (2004-2012). See Table 2 for species codes

YEAR	BOC	HER	MAC	MAS	WHB
2004	377	0	49	37	7057
2005	235	0	74	15	1685
2006	173	0	7	23	1067
2007	760	0	257	47	1418
2008	52	0	46	62	514
2009	549	0	2	11	1247
2010	481	0	4	69	2216
2011	117	0	106	64	1509
2012	183	0	92	40	1337

Table 6: Number of individuals from WGWIDE species sampled in the discards of the Portuguese OTB_DEF fishery (2004-2012). See Table 2 for species codes

YEAR	BOC	HER	MAC	MAS	WHB
2004	1016	0	352	1053	2756
2005	660	0	160	1085	1569
2006	5156	0	225	2704	1356
2007	1810	0	819	3065	632
2008	1345	0	153	3858	86
2009	1270	0	333	2434	1780
2010	201	0	70	3235	2180
2011	331	0	257	1642	605
2012	315	0	740	923	1219

3.4 Total discards

Total discards of WGWIDE species by the Portuguese OTB fisheries are displayed in Table 7 and Table 8. Due to limitations of the current estimation algorithm, discard volumes could not be estimated when frequency of occurrence was lower than 30% (Prista et al., 2012).

Table 7: Volume (in metric tons) and CVs (%, in brackets) of WGWIDE species discarded in the Portuguese OTB_CRU fishery (2004-2012). See Table 2 for species codes. "(a)" = low frequency of occurrence; "(b)" provisional data based on paper logbook records

YEAR	BOC	HER	MAC	MAS	WHB
2004	23 (42%)	0 (0%)	(a)	(a)	2498 (32%)
2005	(a)	0 (0%)	(a)	(a)	980 (40%)
2006	72 (33%)	0 (0%)	(a)	(a)	2252 (37%)
2007	97 (66%)	0 (0%)	(a)	(a)	670 (43%)
2008	(a)	0 (0%)	(a)	25 (32%)	260 (35%)
2009	167 (34%)	0 (0%)	(a)	(a)	368 (32%)
2010	(a)	0 (0%)	(a)	48 (40%)	828 (23%)
2011	8 (38%)	0 (0%)	(a)	52 (39%)	690 (34%)
2012 (b)	34 (71%)	0 (0%)	(a)	(a)	313 (47%)

Table 8: Volume (in metric tons) and CVs (%, in brackets) of WGWIDE species discarded in the Portuguese OTB_DEF fishery (2004-2012). See Table 2 for species codes. "(a)" = low frequency of occurrence; "(b)" provisional data based on paper logbook records

YEAR	BOC	HER	MAC	MAS	WHB
2004	222 (58%)	0 (0%)	(a)	215 (32%)	1080 (43%)
2005	(a)	0 (0%)	(a)	463 (27%)	(a)
2006	945 (24%)	0 (0%)	(a)	1500 (37%)	240 (38%)
2007	281 (24%)	0 (0%)	916 (48%)	4185 (28%)	(a)
2008	273 (37%)	0 (0%)	(a)	3525 (18%)	(a)
2009	154 (37%)	0 (0%)	(a)	1860 (21%)	(a)
2010	(a)	0 (0%)	(a)	4838 (35%)	491 (39%)
2011	(a)	0 (0%)	(a)	954 (24%)	(a)
2012 (b)	80 (30%)	0 (0%)	764 (69%)	(a)	286 (50%)

3.5 Length frequency of discards

Length composition of total discards of WGWIDE species by the Portuguese OTB fisheries are presented in Tables 9-12. Due to limitations of the estimation algorithm (see Section 3.4), length composition at fleet level is only provided for the year × fishery × species combinations where total discards were not null *and* calculated. Global summary statistics of length samples are provided in Table 13 and Table 14.

Table 9: Length composition of discards (no.x1000) of boarfish (BOC) discarded by the Portuguese OTB_CRU fishery (2004, 2006, 2007, 2011, 2012) and OTB_DEF fishery (2004, 2006-2009, 2012). Length compositions were not estimated in the remaining year × fishery combinations (See section 3.4). "(a)" provisional data based on paper logbook records (see Section 2.5)

	OTB_CRU						OTB_DEF					
Class (0.5 cm)	2004	2006	2007	2009	2011	2012 (a)	2004	2006	2007	2008	2009	2012 (a)
1.5	18	0	0	0	0	0	0	0	0	0	0	0
2.0	18	0	0	0	0	0	0	0	0	0	0	0
2.5	0	0	0	0	0	0	0	0	0	0	0	0
3.0	0	0	0	0	0	0	0	0	0	23	0	0
3.5	0	0	0	0	0	0	0	11	27	0	18	0
4.0	6	0	0	0	37	0	53	0	147	137	0	0
4.5	22	0	4	0	37	0	200	55	326	4	18	0
5.0	17	0	0	0	25	0	84	89	809	0	74	0
5.5	2	0	0	0	0	0	25	54	461	0	588	12
6.0	0	0	0	0	12	0	47	38	201	201	499	5
6.5	0	24	6	0	12	4	62	30	139	702	189	14
7.0	0	29	10	0	50	0	146	45	36	397	104	0
7.5	7	0	62	34	100	0	161	4	8	279	226	0
8.0	0	0	24	14	62	7	14	38	0	380	137	108
8.5	<0.5	0	6	21	32	0	3	0	35	428	190	33
9.0	4	21	6	62	0	0	0	37	38	96	143	20
9.5	21	7	0	47	0	0	57	166	95	119	56	20
10.0	57	301	160	93	24	32	485	1755	403	670	164	22
10.5	104	200	459	550	22	44	1437	5108	1224	1355	270	17
11.0	99	317	938	740	39	176	2311	8115	2640	2816	484	83
11.5	85	260	604	1217	38	241	1494	7802	2149	2082	795	129
12.0	156	948	431	1289	13	248	792	5459	1591	1019	972	79
12.5	91	192	227	861	3	107	319	2961	964	681	978	93
13.0	33	103	105	295	3	68	133	1158	531	249	351	170
13.5	11	86	36	44	10	35	48	492	157	176	225	249
14.0	0	25	0	26	0	17	9	55	19	26	71	147
14.5	0	0	0	15	0	9	63	9	4	0	34	103
15.0	0	0	0	0	0	0	63	19	0	0	0	111
15.5	2	0	0	0	0	0	0	0	0	0	0	34
16.0	0	0	0	0	0	0	0	7	0	0	0	48
16.5	0	0	0	0	0	0	0	0	0	0	0	4
17.0	0	0	0	0	0	0	0	0	0	0	0	0
17.5	0	0	0	0	0	0	0	0	0	0	0	0
18.0	0	0	0	0	0	0	0	0	0	0	0	0
18.5	0	0	0	0	0	0	0	0	0	0	0	0
19.0	0	0	0	0	0	0	0	0	0	0	0	0
19.5	0	0	0	0	0	0	0	0	0	0	2	0
20.0	0	0	0	0	0	0	0	0	0	0	0	0

Table 10: Length composition of discards (no.x1000) of Atlantic mackerel (MAC) discarded by the Portuguese OTB_DEF fishery (2007, 2012). Length compositions were not estimated in the remaining year × fishery combinations (See section 3.4). "(a)" provisional data based on paper logbook records (see Section 2.5)

	OTB_DEF	
Class (1 cm)	2007	2012 (a)
11	0	0
12	0	0
13	0	0
14	0	0
15	0	0
16	0	0
17	31	0
18	0	3
19	596	524
20	4003	1027
21	2650	2819
22	700	3530
23	1772	1002
24	1482	208
25	814	152
26	103	43
27	52	24
28	5	19
29	21	11
30	5	15
31	43	0
32	0	0
33	0	0
34	0	0
35	0	0
36	0	11
37	0	11
38	0	21
39	0	11
40	0	34
41	0	0
42	0	21
43	0	0

Table 11: Length composition of discards (no.x1000) of chub mackerel (MAS) discarded by the Portuguese OTB_CRU fishery (2008, 2010, 2011) and OTB_DEF fishery (2004-2011). Length compositions were not estimated in the remaining year × fishery combinations (See section 3.4)

	OTB_CRU			OTB_DEF							
Class (1 cm)	2008	2010	2011	2004	2005	2006	2007	2008	2009	2010	2011
11	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	8	0	0	0	0	0	0
13	0	0	0	0	13	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	68
15	0	0	0	0	8	38	377	63	0	0	98
16	0	0	6	0	60	11	388	580	537	0	58
17	0	0	0	0	431	729	2537	1744	1714	236	225
18	0	0	9	0	1465	5963	4456	2167	1999	3466	761
19	0	0	114	0	1477	9260	6743	3744	1636	7055	944
20	8	0	50	28	406	4501	7685	4591	1432	6721	762
21	0	4	34	100	156	2413	8338	7386	1854	7504	1021
22	21	57	9	205	130	995	6771	10421	2185	9356	937
23	9	59	5	192	450	761	4282	4863	2820	8534	1332
24	23	93	20	217	721	460	2930	2414	3122	4913	1035
25	23	60	20	96	489	473	2022	1047	2699	3388	749
26	26	12	43	263	217	321	1695	1318	1273	2400	716
27	21	43	34	136	205	224	949	1042	451	1107	310
28	27	50	63	200	45	111	894	461	100	660	238
29	9	6	47	195	35	51	321	337	52	386	298
30	8	0	7	17	2	21	142	100	56	129	86
31	16	3	7	6	0	24	42	33	11	19	29
32	0	0	0	0	0	11	38	27	45	0	4
33	0	2	0	0	0	0	6	4	0	5	30
34	0	0	0	0	0	0	7	4	22	0	4
35	0	0	0	0	0	0	0	16	27	0	0
36	0	0	0	0	0	0	2	12	0	0	0
37	0	0	0	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0	0	0	0
39	0	0	0	0	0	0	0	0	0	0	0
40	0	0	0	0	0	0	0	0	0	0	0
41	0	0	0	0	0	0	0	0	0	0	0
42	0	0	0	0	0	0	0	0	0	0	0
43	0	0	0	0	0	0	0	11	0	0	0
44	0	0	0	0	0	0	0	0	0	0	0

Table 12: Length composition of discards (no.x1000) of blue whiting (WHB) discarded by the Portuguese OTB_CRU fishery (2004-2011) and OTB_DEF fishery (2004, 2006, 2010). Length compositions were not estimated in the remaining year × fishery combinations (See section 3.4). "(a)" provisional data based on paper logbook records (see Section 2.5)

	OTB_CRU									OTB_DEF			
Class (1 cm)	2004	2005	2006	2007	2008	2009	2010	2011	2012 (a)	2004	2006	2010	2012 (a)
5	0	0	0	0	0	0	0	0	0	0	7	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	10	0	0
8	0	0	0	0	0	0	0	0	0	0	67	0	0
9	0	0	0	0	0	0	0	0	0	0	382	0	0
10	0	0	0	0	0	0	0	0	0	0	354	0	0
11	0	0	0	0	0	24	0	0	21	0	58	0	24
12	0	0	0	0	0	334	7	0	52	0	35	78	48
13	2	0	20	0	0	443	135	0	100	0	107	60	410
14	1476	0	103	0	0	540	692	0	255	0	315	1758	1995
15	8137	0	546	9	0	893	1112	12	447	1161	1498	4868	3356
16	6458	113	344	8	0	1428	1110	579	504	5081	1334	5990	1553
17	1366	326	1409	18	0	1836	1304	1122	350	10066	561	2141	459
18	333	214	603	27	0	2001	1738	909	329	4003	363	721	840
19	806	87	1229	18	13	1769	2438	1690	442	1443	493	400	634
20	3359	130	1335	51	104	818	1549	1795	747	2633	695	225	361
21	6563	176	2490	263	194	167	977	1569	788	2081	367	222	148
22	5074	257	1577	1189	361	0	1546	1666	361	1155	232	518	101
23	3305	653	2701	2322	246	0	1114	1225	122	441	261	241	42
24	2694	874	1471	1396	571	16	926	731	74	230	173	172	32
25	1958	1267	2860	512	504	29	473	279	72	220	113	0	26
26	689	1219	3546	454	460	117	197	98	58	113	90	0	24
27	494	994	1010	218	167	110	54	62	104	42	46	0	0
28	377	794	930	239	74	76	41	51	105	13	4	4	0
29	95	526	513	86	25	29	24	51	49	0	4	0	0
30	83	394	559	41	34	68	31	41	46	0	0	0	0
31	48	198	740	26	17	0	5	12	5	0	0	0	0
32	53	127	192	1	10	0	0	16	12	0	0	0	0
33	9	30	112	10	10	0	14	3	2	10	0	0	0
34	8	34	63	20	3	13	13	14	0	0	0	0	0
35	12	23	13	6	0	0	0	4	8	0	0	0	0
36	8	5	0	0	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0	0	0	0
38	8	0	0	0	0	0	0	0	0	0	0	0	0

Table 13: Length frequency of discards (in cm) of WGWIDE species sampled onboard the Portuguese OTB_CRU fishery (2004-2012). See Table 2 for species codes

Taxa	n	Mean	SD	Range
BOC	2885	11.3	1.4	2.0-15.5
MAC	610	21.6	2.9	14-33
MAS	368	25.2	3.9	16-42
WHB	17733	20.9	4.3	10-38

Table 14: Length frequency of discards (in cm) of WGWIDE species sampled onboard the Portuguese OTB_DEF fishery (2004-2012). See Table 2 for species codes

Taxa	n	Mean	SD	Range
BOC	12013	11.1	1.5	3.0-19.5
MAC	3108	21.8	2.8	11-42
MAS	19994	21.2	2.8	12-43
WHB	12182	17	2.6	5-33

3.6 Age composition of discards

The fleet level age compositions of WGWIDE species' discards (in numbers) are displayed in Tables 15-17. Due to limitations of the estimation algorithm (see Section 3.4), age composition at fleet level is only provided for the year × fishery × species combinations where total discards were not null *and* above the 30% frequency of occurrence threshold (See section 2.5). Age composition is not provided for boarfish because the species is not aged at IPMA.

Table 15: Age composition of Atlantic mackerel (MAC) discarded by the Portuguese OTB_DEF fishery (2007, 2012) (no.x1000). Age compositions were not estimated in the remaining year × fishery combinations (See section 3.4). "(a)" provisional data based on paper logbook records (see Section 2.5)

	OTB_DEF	
age class	2007	2012 (a)
0	3668	3138
1	5955	6036
2	2623	199
3	21	4
4	7	8
5	3	15
6	0	19
7	0	20
8	0	15
9	0	12
10	0	19
11+	0	0

Table 16: Age composition of chub mackerel (MAS) discarded by the Portuguese OTB_CRU fishery (2004-2012) and OTB_DEF fishery (2004, 2006, 2010) (no.x1000). Age compositions were not estimated in the remaining year × fishery combinations (See section 3.4)

	OTB_CRU			OTB_DEF							
age class	2008	2010	2011	2004	2005	2006	2007	2008	2009	2010	2011
0	3	23	93	164	4218	10394	13870	7602	979	19500	1968
1	114	157	232	936	1331	14628	25946	25665	15109	16359	5617
2	71	207	140	555	757	1279	10227	8973	5899	19994	2082
3	4	3	6	1	5	26	419	102	9	24	38
4	0	0	0	0	0	0	155	5	16	0	2
5	0	0	0	0	0	0	6	14	22	0	<0.5
6	0	0	0	0	0	0	<0.5	11	0	0	0
7	0	0	0	0	0	0	0	1	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0
11+	0	0	0	0	0	0	0	11	0	0	0

Table 17: Age composition of blue withing (WHB) discarded by the Portuguese OTB_CRU fishery (2004-2011) and OTB_DEF fishery (2004, 2006, 2010) (no.x1000). Age compositions were not estimated in the remaining year × fishery combinations (See section 3.4). "(a)" provisional data based on paper logbook records (see Section 2.5)

	OTB_CRU									OTB_DEF			
age class	2004	2005	2006	2007	2008	2009	2010	2011	2012 (a)	2004	2006	2010	2012 (a)
0	2226	624	1562	9	23	4387	3890	2566	211	1464	4221	10677	498
1	23629	353	8910	1972	749	4716	6571	2795	2071	21331	2503	5509	6829
2	10905	3376	5179	1693	986	1102	3360	5739	1114	4845	488	885	1840
3	5353	1882	3491	1412	590	319	1254	639	882	900	207	283	581
4	979	1193	2038	975	238	80	266	72	572	127	91	35	261
5	183	768	1804	505	127	53	103	68	190	14	44	8	41
6	92	160	959	207	59	36	40	20	7	10	13	1	1
7	9	25	308	90	16	11	12	12	3	0	1	0	0
8	36	62	49	26	5	3	3	9	3	0	0	0	0
9	0	0	62	19	1	1	1	4	<0.5	0	0	0	0
10	0	0	0	6	0	0	0	3	<0.5	0	0	0	0
11+	0	0	0	0	0	0	0	0	0	0	0	0	0

References

Prista, N., Fernandes, A.C., Martins, M.M., Gonçalves, P., 2012. Discards of boarfish, Atlantic mackerel, chub mackerel and blue whiting by the Portuguese bottom otter trawl fleet operating in the Portuguese ICES Division IXa. Working Document for the ICES Working Group on on Widely Distributed Stocks (WGWIDE), Lowestoft, UK, 21-27 August 2012, and references therein.

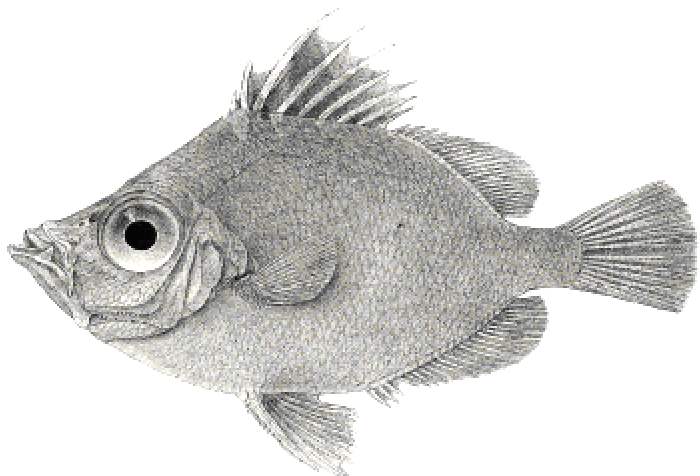
Working Document

Working Group on Widely Distributed Stocks

Copenhagen, Denmark, 27 August-2 September 2013

Working Group on International Pelagic Surveys

Copenhagen, Denmark, 20-24 January 2014



Day (1966)

On the implementation of a modelled TS relationship for boarfish (*Capros aper)* abundance estimates.

Ciaran O'Donnell

Introduction

Conversion of acoustic density to fish abundance is done by use of a species-specific target strength (TS) that describes the sound-scattering potential of one individual fish. Abundance estimation techniques from acoustic survey data rely on relationships between TS and fish length (L) of the form $TS= m \log_{10} (L) - b$. Commonly, the slope parameter m is fixed to the theoretical value of 20, indicating a proportional relationship between the square of the fish length and acoustic backscatter (McClatchie et al., 2003), and a species-specific value for the intercept parameter b is used (Foote, 1987). Currently, TS–L relationships are available for many important commercial species or species groups whose stock sizes are regularly estimated by acoustic surveys. TS–L relationships are usually estimated based on the *ex situ* measurements of immobilized or dead fish, fish in cages, or those observed *in situ* in their natural habitat. The majority of the currently accepted and practically applied relationships to convert fish length into TS are based on extensive *in situ* datasets.

The boarfish fishery developed rapidly from incidental by-catch to a dedicated international pelagic fishery. The requirement for a fishery independent means of assessment was brought to the forefront and prioritized along with research into life history. At the time, no species-specific TS–L relationship was available for boarfish. Basic knowledge of their main sound-scattering organ the swimbladder was also lacking, except that it was "relatively large" (Fish, 1948) and of the physoclistous type (Marshall, 1960). Preliminary estimates of abundance and biomass of the stock, therefore, had to be based on the use of a range of "candidate" TS–L relationships previously determined for gadoids, Atlantic herring, and snipefish (Macroramphosus spp.). These resulted in up to 20-fold differences in estimated total stock biomass (O'Donnell *et al,* 2011). To reduce this uncertainty, an effort to generate a boarfish-specific TS–L relationship was initiated.

Modeling was carried out on boarfish samples collected in 2011 and have been applied to abundance data collected during the 2011-2013 survey time series based on work carried out by Fassler *et al.* (2013).

Calculation of a new survey abundance index using a new TS-length relationship

Preliminary results of modeled data provided a TS-L relationship that was applied to survey data (2011 & 2012) and was submitted to WGWIDE in 2012. (Fassler *et al,* unpublished data).

$$\textbf{TS = 21.8 log10 L – 65.98}$$

This working document revisits this modeled data after peer review and applies the final version to the survey index 2011-2013 using the TS-L relationship of (Fassler *et al,* 2013):

$$\textbf{TS = 21.8 log10 L – 66.2}$$

The revision of TS has changed the value specific to boarfish by 0.2dB which has the net affect of increasing the estimates by c.5%.

A full detailed account of the steps carried out to determine this value for boarfish is presented in Fassler *et al,* 2013.

It is recommended that WGWIDE adopt this TS-L relationship for boarfish going forward.

Revised time series

Table 1. Revised boarfish acoustic survey time series.

Years	2011	2012	2013
0	-	-	-
1	4.9	21.5	-
2	11.3	10.8	78.0
3	54.2	174.1	1,842.9
4	176.0	64.8	696.4
5	404.7	95.0	381.6
6	1,068.0	736.1	253.8
7	1,052.0	973.8	1,056.6
8	632.5	758.9	879.4
9	946.1	848.6	800.9
10	831.8	955.9	703.8
11	259.7	650.9	263.7
12	457.2	1,099.7	202.9
13	281.7	857.2	296.6
14	257.2	655.8	169.8
15+	1,746.0	6,353.7	1,464.3
TSN (mil)	8,183	14,257	9,091
TSB ('000t)	456,115	863,446	439,890
SSB ('000t)	455,375	861,544	423,158
CV	17.5	10.6	17.5

Table 2. Revised biomass and abundance by category 2011-2013.

			2011
	Abun (mil)	**Biomass (t)**	**%**
Total estimate			
Definitely	7,049	393,893	86.4
Probably	1,134	62,222	13.6
Mixture	-	-	-
Total estimate	**8,183**	**456,115**	**100**
Possibly			
SSB Estimate			
Definelty	7,019	393,312	86.4
Probably	1,126	62,063	13.6
Mixture	0	0	0.0
SSB estimate	**8,145**	**455,375**	**100**
Possibly	-	-	

			2012
	Abun (mil)	**Biomass (t)**	**%**
Total estimate			
Definitely	11,684	708,019	82.0
Probably	2,072	123,723	14.3
Mixture	501	31,704	3.7
Total estimate	**14,257**	**863,446**	**100**
Possibly	16	1,017	
SSB Estimate			
Definelty	11,615	706,582	82.0
Probably	2,050	123,286	14.3
Mixture	500	31,676	3.7
SSB estimate	**14,165**	**861,544**	**100**
Possibly	16	1,017	

			2013
	Abun (mil)	**Biomass (t)**	**%**
Total estimate			
Definitely	8,834	431,571	98.1
Probably	240	7,187	1.6
Mixture	17	1,139	0.3
Total estimate	**9,091**	**439,897**	**100**
Possibly	-	-	
SSB Estimate			
Definelty	8,120	416,124	98.3
Probably	179	5,895	1.4
Mixture	17	1,139	0.3
SSB estimate	**8,316**	**423,158**	**100**
Possibly	-	-	

Table 3. Revised biomass and abundance by age 2011-2013.

2011

Length	Age	(years)														Abundance	Biomass	Mn wt
(cm)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	(millions)	(000s t)	(g)
4.5																		
5																		
5.5																		
6																		
6.5																		
7																		
7.5	4.9	3.7														8.6	0.1	10.6
8		0.1	0.1													0.2		12.7
8.5																		
9																		
9.5		4.4	16.2	8.8												29.4	0.6	20.6
10		0.7	4.3	12.1	5.0	0.7										22.7	0.5	23.9
10.5		2.4	2.4	33.0	23.6	2.4										63.6	1.7	27.4
11				34.5	39.8	18.6	5.3									98.1	3.1	31.3
11.5			31.4	31.4	125.9	110.4	65.8	15.9								380.6	13.5	35.5
12					97.9	456.8	97.9	163.1								815.6	32.7	40.1
12.5				56.3	112.7	281.8	450.9		225.5	169.1	56.3					1352.5	60.9	45.0
13						197.4	197.4	263.3	263.3	131.6	65.8	65.8	65.8		65.8	1316.3	66.3	50.4
13.5							190.2	190.2	126.8	190.2	63.4	63.4	126.8		317.1	1268.3	71.2	56.1
14									241.5	184.0	55.7	184.0		55.7	176.5	897.4	55.9	62.3
14.5							44.5		89.0	89.0		89.0	89.0	133.6	222.6	756.7	52.1	68.8
15										49.4				49.4	395.5	494.5	37.5	75.8
15.5										18.4	18.4	55.0		18.4	276.1	386.4	32.2	83.3
16															184.6	184.6	16.9	91.2
16.5															81.5	81.5	8.1	99.7
17															25.6	25.6	2.8	108.6
17.5															0.7	0.7	0.1	118.0
18																		
18.5																		
19																		
19.5																		
20																		
SSN		4.5	43.4	165.0	401.4	1067.6	1052.0	632.5	946.1	831.8	259.7	457.2	281.7	257.2	1746.0	8,145.8		
SSB		0.1	1.4	5.8	15.4	45.5	50.4	31.0	51.7	47.8	14.4	29.0	16.6	18.0	128.2		455.4	
Mn wt (g)	10.6	18.9	29.8	34.7	38.2	42.6	47.9	49.1	54.6	57.4	55.5	63.5	58.8	69.8	433.3			
Mn L (cm)	7.7	9.3	11	11.6	12	12.5	13	13.1	13.6	13.8	13.7	14.3	13.9	14.8	89.6			

2012

Length	Age	(years)														Abundance	Biomass	Mn wt
(cm)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	(millions)	(000s t)	(g)
4.5																		
5																		
5.5																		
6																		
6.5																		
7																		
7.5	7.3															7.3	0.1	10.6
8																		
8.5																		
9	14.2															14.2	0.3	17.7
9.5		10.8	53.9													64.7	1.3	20.6
10			74.6	28.0	18.6											121.2	2.9	23.9
10.5			41.6	11.9		11.9	5.9									71.3	2.0	27.4
11			4.0	20.0	12.0	24.1	12.0	12.0								84.2	2.6	31.3
11.5				4.9	29.7	118.6	49.4	29.7	9.9							242.2	8.6	35.5
12					11.7	198.6	163.6	140.2	105.1	58.4		11.7				689.3	27.6	40.1
12.5					23.0	229.6	344.4	183.7	206.7	160.7	160.7	45.9				1354.7	61.0	45.0
13						153.3	268.2	306.6	306.6	306.6	191.6	306.6	76.6	76.6	306.6	2299.2	115.8	50.4
13.5							130.2	86.8	173.6	260.3	173.6	347.1	260.3	217.0	911.2	2560.0	143.6	56.1
14									46.8	93.7	93.7	281.0	374.7	140.5	1264.5	2294.9	142.9	62.3
14.5										76.1		76.1	114.2	190.4	1027.9	1484.8	102.2	68.8
15											31.3	31.3	31.3	31.3	1095.6	1220.8	92.6	75.8
15.5															898.2	898.2	74.8	83.3
16															446.7	446.7	40.8	91.2
16.5															259.2	259.2	25.8	99.7
17															27.6	27.6	3.0	108.6
17.5															24.4	24.4	2.9	118.0
18															7.6	7.61	0.97	127.9
18.5															84.3	84.31	11.67	138.4
19																		
19.5																		
20																		
SSN		4.3	122.7	58.1	91.2	734.9	973.2	758.9	848.6	955.8	650.9	1099.7	857.2	655.8	6353.8	14,164.9		
SSB		0.1	3.0	1.6	3.3	31.3	45.2	35.6	42.0	50.7	34.8	62.6	52.0	40.3	459.1		861.5	
Mn wt (g)	15.3	20.6	23.9	27.7	35.6	42.5	46.4	47	49.5	53	53.5	56.9	60.7	61.4	399.4			
Mn L (cm)	8.7	9.8	10.2	10.8	11.7	12.5	12.9	12.9	13.1	13.5	13.5	13.8	14.1	14.2	87.3			

Table 3. cont.

2013

Length (cm)	Age 1	(years) 2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Abundance (millions)	Biomass (000s t)	Mn wt (g)
4.5																		
5																		
5.5																		
6																		
6.5																		
7																		
7.5																		
8		9.7														9.7	0.1	12.7
8.5																		
9		68.3	68.3													136.6	2.4	17.7
9.5			547.9													547.9	11.3	20.6
10			1120.2													1120.2	26.7	23.9
10.5			100.8	504.0	151.2											756.0	20.7	27.4
11			5.6	163.5	78.9	11.3	11.3									270.6	8.5	31.3
11.5				15.7	36.7	36.7	31.4	3.5	3.5	1.8						129.2	4.6	35.5
12				13.2	56.3	72.8	125.7	39.7	26.5						3.3	337.5	13.5	40.1
12.5					30.4	54.7	255.3	224.9	85.1	36.5	12.2		6.1	6.1	6.1	717.2	32.3	45.0
13					18.0	35.9	278.2	251.3	215.4	107.7	53.9	18.0	26.9	9.0	44.9	1059.1	53.4	50.4
13.5					10.3	30.7	256.2	225.4	215.2	143.5	61.5	51.2	41.0	20.5	112.7	1168.1	65.5	56.1
14							73.4	97.8	220.1	269.0	97.8	36.7	85.6	12.2	244.6	1137.3	70.8	62.3
14.5						11.7	11.7	23.4	35.2	93.8	11.7	70.3	70.3	70.3	351.7	750.2	51.6	68.8
15							13.3	13.3		26.7	26.7	26.7	66.7	26.7	253.5	453.7	34.4	75.8
15.5										25.0				25.0	237.2	287.2	23.9	83.3
16															138.6	138.6	12.6	91.2
16.5															48.5	48.5	4.8	99.7
17															20.9	20.9	2.3	108.6
17.5															2.7	2.7	0.3	118.0
18																		
18.5																		
19																		
19.5																		
20																		
SSN			1211.7	646.0	366.5	253.8	1056.6	879.4	800.9	703.8	263.7	202.9	296.6	169.8	1464.5	8,316.3		
SSB			28.6	18.6	12.6	11.4	52.8	45.9	44.1	42.5	15.6	12.9	19.2	11.6	107.5		423.2	
Mn wt (g)		17.1	22.9	28.7	34.1	44.8	50	52.2	55	60.4	59.3	63.7	64.6	68.2	73.4			
Mn L (cm)		9.1	10.1	10.9	11.5	12.7	13.2	13.4	13.6	14.1	14	14.3	14.4	14.7	15			

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27 August – 02 September 2013

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Annex 2A – Stock Annex. Northeast Atlantic mackerel

Quality Handbook	ANNEX: WGWIDE-MAC-NEA

Stock specific documentation of standard assessment procedures used by ICES

Stock	Mackerel in the northeast Atlantic
Working Group:	Working Group on Widely Distributed Stocks
Date:	8 September 2009, Updated 30 August 2010, 29 August 2011
By	T. Jansen, T. Brunel, A. Campbell, C. Main, L. Readdy, L. Nøttestad, E.M.C. Hatfield

A. General

A.1. Stock definition

ICES currently uses the term northeast Atlantic mackerel to define the mackerel present in the area extending from the Iberian peninsula in the south to the northern Norwegian Sea in the north, and Iceland in the west to western Baltic Sea in east.

Even though spawning occurs widely on the shelf from Biscay to the Norwegian Sea, there are two loci of increased intensity (Figure A.3.2.1). One elongated area along the shelf break from Spanish and Portuguese waters in March, around Ireland to the west of Scotland where spawning peaks in June (Beare and Reid 2002). The other area is in the central North Sea in May-July. Only the stock in the North Sea is sufficiently distinct to be identified as a separate spawning component. Since the egg distributions in south and west overlap in the Bay of Biscay, it is impossible to define the northern border of a southern component and the southern border of a western component. Since it is currently impossible to allocate catches to the stocks previously considered by ICES, they are at present, for practical reasons, considered as one stock: the northeast Atlantic mackerel Stock.

Tagging experiments have demonstrated that after spawning, fish from southern and western areas migrate to feed in the Norwegian Sea and the North Sea during the second half of the year (Uriarte *et al*. 2001). In the North Sea they mix with the North Sea component. However, in order to keep track of the development of the spawning biomasses in the different spawning areas, the northeast Atlantic mackerel stock is divided into three area components: the western spawning component, the North Sea spawning component, and the southern spawning component. By convention the catches from the components are separated according to the area in which they are taken:

Spawning component	Western	Southern	North Sea
Spawning Areas	VI, VII, VIIIa,b,d,e.	VIIIc, IXa.	IV, IIIa.

The western component is defined as mackerel spawning in the western area (ICES Divisions and Subareas VI, VII, and VIII a,b,d,e). This component currently comprises most of the northeast Atlantic stock. Similarly, the southern component is defined as mackerel spawning in the southern area (ICES Divisions VIIIc and IXa). Although the North Sea component has been at an extremely low level since the early 1970s, ICES regards the North Sea component as still existing. This component spawns in the North Sea and Skagerrak (ICES Subarea IV and Division IIIa).

A.2. Fishery

The patterns of NEA mackerel fishing are very variable throughout the wide mackerel distribution and between the seasons due to migration, spawning, feeding and over-wintering. The sections below outline the historic changes of the mackerel fisheries and encapsulate the main actors in the recent years.

A.2.1. Mackerel fishing since the 1960s

The largest fisheries have been on the over-wintering and early spawning migration phases. The geographic area of these fisheries has changed over time.

In the 1960s a Norwegian fishery in the Northern North Sea unparalleled in size arose with the development of modern sonar, single vessel purse seining, power blocks and hydraulic fish pumps. After a few years of extreme over-fishing of the North Sea component, the catches dropped to the present day level until, in the late 1970s, the stock component collapsed and the fishery ceased. Meanwhile in the Cornwall (UK), in Q4 and Q1 an intensive fishery by USSR and UK had built up; this effectively ended with the introduction of a closed box in the early 1980s. While the first quarter fishery since then came from the west of Orkney to the west of Ireland; the fourth quarter fishery moved to the west of Scotland and the North of Ireland in the 1980s and by the 1990s this had gradually shifted to the Northern North Sea. A summer fishery in the international zone of Division IIa has developed since the late 1980s, in most recent years this has extended into the Icelandic zone. Peak fisheries in the Iberian region have shifted slightly in time from early Q2 to late Q1. This fishery is targeting spawning mackerel.

A.2.2. Recent year’s major fisheries by area

The largest fishery is in the Northern North Sea (Subareas IV), by purse seine and pelagic trawl in late Q3, Q4 and early Q1. The catches are predominantly taken by the Norwegian fleet, followed in size by Scottish, English, Danish, Irish and Faroese fleets.

To the west of the British Isles (Subarea VI and Divisions VIIb,c) most catches are taken by the Scottish and Irish pelagic trawler fleets, while Subdivisions VIId-j are also fished by the English fleet and Dutch, French and German freezer trawlers.

In the Norwegian Sea (Subarea II) most catches are taken in Q3. The major fisheries are: Russian freezer trawlers (55 – 80 m) that target mackerel, blue whiting and herring at the same time. Most recently Icelandic vessels targeting herring have begun to land much mackerel. The big Norwegian fishery has ceased.

The Spanish fleet operating off the Iberian Peninsula (Divisions VIIIa and IXc) consists of demersal trawlers, purse seiners between 10 – 32 m and a large artisanal fleet with vessels between 2 and 34 m. Most of the landings are adult mackerel and the fishery has shifted slightly in time from peaking in early Q2 to late Q1.

The main mackerel catching countries in recent years continue to be Scotland, Norway, Spain, Ireland, the Netherlands, Denmark and Russia. Icelandic catches now also contribute a significant amount to the total. England & Wales, the Faroe Islands, France, Germany, Northern Ireland, Portugal and Sweden all have catches over 1,000t (combined catch 78,000t in 2007).

A.3. Ecosystem and behavioural aspects

A.3.1. Feeding

Post larval mackerel feed on a variety of zooplankton and small fish. They prefer larger prey species over smaller prey (Pepin *et al*. 1987; Langoy *et al*. 2006). Feeding patterns vary seasonally, spatially and with size. Mackerel stop feeding almost completely during winter. Main zooplankton prey species in the North Sea are: Copepods (mainly *Calanus finmarchicus*), euphausiids (mainly *Meganyctiphanes norvegica*), while primary fish prey species are: sandeel, herring, sprat, and Norway pout (Walsh and Rankine 1979; Mehl and Westgård 1983; ICES 1989; ICES 1997a). Mackerel and horse mackerel are responsible for virtually all of the predation on 0- group herring as well as a large part of the consumption of 0-group Norway pout and of all ages of sandeel in the North Sea (ICES 2008b). In the Norwegian Sea euphausiids, copepods (mainly *Calanus finmarchicus* and *Oithona*), *Limacina retroversa, Maurolicus muelleri,* amphipods, Appendicularia and capelin are the main diet during the summer feeding migration (Langoy, *et al* 2006; Prokopchuk 2006; Langoy, *et al* 2010).

A.3.2. Spawning

Mackerel spawn at any time of the day or night and the eggs remain in the upper water masses (Nichols and Warnes 1993). Mackerel egg surveys have been conducted since 1968. In the later years these surveys have been carried out every third year, with the North Sea and western areas in alternating years.

Even though spawning occurs widely on the shelf from Biscay to the Norwegian Sea, there are two loci of increased intensity (Figure A.3.2.1). One elongated area along the shelf break from Spanish and Portuguese waters in March, around Ireland to the west of Scotland where spawning peaks in June (Beare and Reid 2002; Iversen 2002). Since the egg distribution of the southern and western components overlaps in the Bay of Biscay, it is impossible to define the northern border of the southern component and the southern border of the western component. The other area is in the central North Sea in May-July.

Spawning activity in the south and west has shifted to the north through the '80s and '90s, declining in the south and rising in the north (Beare and Reid 2002). In the North Sea there is a westward shift in the main spawning area from the central part of the North Sea in the early 1980s to the western part in recent years (2005 and 2008) (Anon 2009).

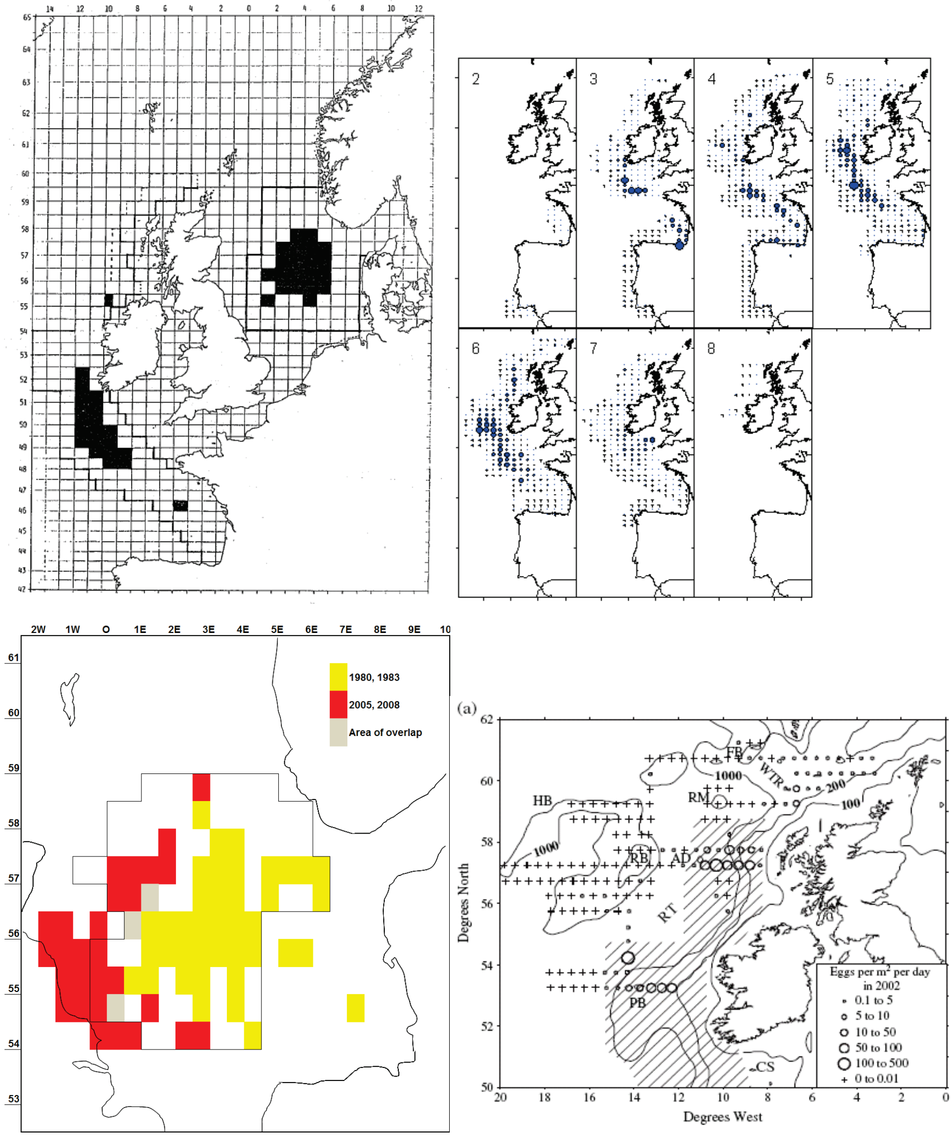

Figure A.3.2.1. NEA mackerel spawning areas. Upper left: Shaded areas indicate > 100 eggs/m2 in at least two of the years in the period 1977-1988 (from (ICES 1990)**). Upper right: Average distribution of mackerel eggs by ICES statistical rectangle in 1992-2007, each map represents a survey between February and August (from** (Anon 2009)**). Lower left: North sea spawning area defined by a daily egg production of at least 50 mackerel eggs per m² of sea surface in any of the years 1980, 1983, 2005 and 2008 (from** (Anon 2009)**). Lower right: Experimental survey in May 2002 (from** (Dransfeld, *et al* 2005)**).**

A.3.3. Migration

Mackerel perform extensive migration between spawning, feeding and over-wintering areas. The migration pattern has changed substantially through time.

It is well known that swimming speed is related to fish length (Pepin *et al*. 1988). Tagging has shown that juveniles of the southern/western component do not migrate as far as the adults (Uriarte *et al.* 2001) and in the Norwegian Sea it is the larger fish that reach furthest to the north and northwest during the feeding migration in summer (Holst and Iversen 1992; Nøttestad *et al*. 1999; Anon 2009; ICES 2009) and in the east end of the feeding migration large mackerel arrive before and leave later than small mackerel (Jansen and Gislason 2011).

Temperature has been suggested as a cause of the observed changes in the western and southern mackerel pre-spawning migration (Walsh and Martin 1986; Reid *et al*. 2003). The location before the onset of migration in winter, that ultimately ends at the spawning grounds in the spring, is probably constrained by temperature (Reid *et al*. 2001), as are the migration path and speed (Walsh *et al*. 1995; Reid *et al*. 1997). However, other factors than temperature preferences are affecting the mackerel behaviour and can in different scenarios have different weights. D'Amours and Castonguay (1992) showed that mackerel from the northern component of the west Atlantic mackerel migrated into Cabot Straight with approx. 4 ºC in order to get to their spawning grounds. They argued that the fish's thermal preferences could be subordinate to their reproductive requirements, a point supported by the fact that this stock always enter the Cabot Straight around the same date (Anonymous 1896; Castonguay and Beaulieu 1993). Studies of the post-spawning feeding migration are limited. Patterns of food and temperature related distributions in the Norwegian Sea in the summer are emerging from summer surveys in the Norwegian Sea in 1992 and 2002-2009. However, the big picture of when and where is the thermal preference dominating/subordinate in relation to other activities like feeding, spawning and predator avoidance remains to be drawn.

Western and southern stocks

Tagging studies (Uriarte and Lucio 1996; Belikov *et al*. 1998; Uriarte *et al*. 2001) have demonstrated that mackerel travel from both the western and southern spawning ground north up into the Norwegian and North Seas. The migration can be considered as having two elements;

1. A post spawning migration from the spawning areas along the western European shelf edge (Uriarte *et al*. 2001)
2. A pre-spawning migration from feeding grounds in the North and Norwegian Seas (Walsh *et al*. 1995; Reid *et al*. 1997). This pre-spawning migration includes shorter or longer halts that sometimes are referred to as over-wintering.

The changes in the timing of the pre-spawning migration of the western spawning component of the north-east Atlantic mackerel have been dramatic over the last 30 years (Figure A.3.3.1.): The migration passed through the west of Scotland area in September 1975. By the late 1990s it passed through this area in January/February. This appears to have been fairly consistent up to 2005 (Walsh and Martin 1986; Reid *et al*. 2003; Reid *et al*. 2006) and the pattern in the last years has been variable but without a common trend: 2006-2007 with later migration (ICES 2007a) and in 2008 commercial fishing and IBTS Q1 data suggests that the stock initiated the south-western migration earlier. There are also indications of variation in spawning time:

The Spanish spring fishery in the Bay of Biscay has been occurring earlier each year, and since this fishery is targeting spawning mackerel, this indicates that the spawning in the southern component occurs earlier each year (Punzon and Villamor 2009). Recently and in the '90s, it has been documented that the mackerel distribution in the Nordic Seas in the summer covers a vast area up to 73-75ºN and from Norway in the east and beyond Iceland in the west. The dynamics and environmental drivers of the mackerel distribution are not yet uncovered. Surveys in recent years indicate substantial interannual variation and provides hypothesis on relations to temperature and food (Holst and Iversen 1992; Holst and Iversen 1999; Anonymous 2002; Anonymous 2003; Gill, *et al* 2004; Anonymous 2005; ICES 2006b; ICES 2007b; ICES 2009; ICES 2009).

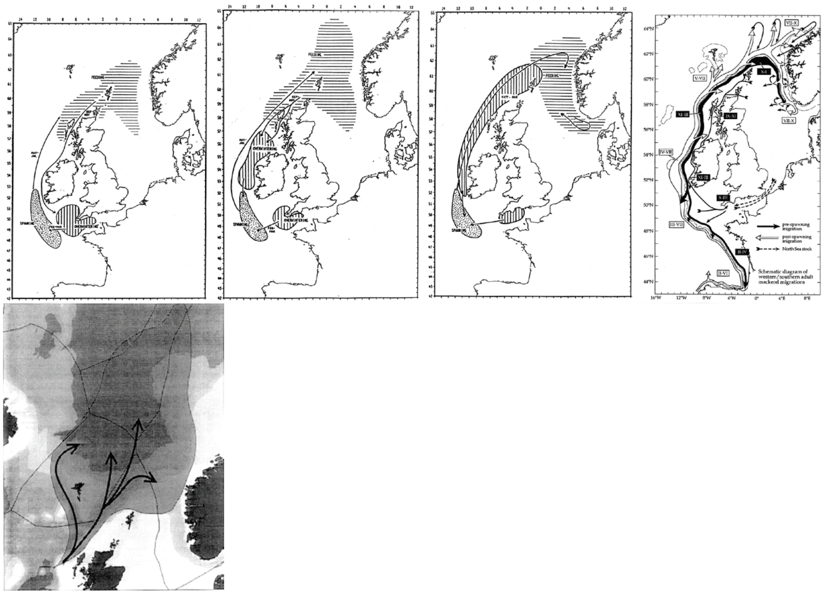

Figure A.3.3.1. Schematic outline of the migration of the western (+ southern in top right map) adult mackerel through time. From left: late 1970s (ICES 1990)**, early 1980s** (ICES 1990)**, latter half of 1980s** (ICES 1990)**, mid 1990** (Anon 1997) **and** (Belikov, *et al* 1998)**.**

North Sea stock

Due to the inability to separate individuals from the North Sea stock and the other stocks, our perception of the distribution in time and space of the smaller North Sea stock is based on observations from before the stock collapsed in the late 1960s.

After spawning the stock spreads out. The post-spawning feeding migration takes the mackerel north into the Northern North Sea and the Norwegian Sea, east into the transition waters and western Baltic Sea, while parts remain in the North Sea. Later in the autumn the mackerel move to deeper waters in the northern part of the Norwegian Trench, Shetland area, and Viking Bank for wintering. In April/May, they return to the surface layer for feeding, and migrate towards the spawning area in the central part of the North Sea and Skagerrak (Revheim 1951; Zijlstra and Postuma 1966; Agger 1970a; Agger 1970b; Postuma 1972; Lindquist and Hannerz 1974; Hamre 1978; Iversen 2002)

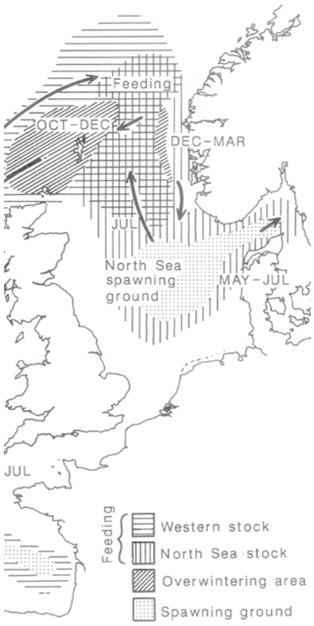

Figure A.3.3.2. Assumed migration and area distribution of the North Sea mackerel. From (ICES 1990)**.**

A.3.4. By-catch

Only fragmented information on by-catch is available.

NEA mackerel and NSS herring currently have a pronounced overlap in spatial distribution in the south-western and northern parts of the Norwegian Sea. Mackerel was caught together with considerable amounts of herring in the same trawl hauls, both in several commercial fisheries and in international surveys, suggesting that by-catch is an issue for the pelagic trawl fisheries in this area (ICES 2008a).

The distribution of chub mackerel (*Scomber colias*) overlaps with the mackerel distribution in the southern area, with some substantial catches in Division IXa.

B. Data

In this section data used directly in the analytical assessment are outlined. This includes:

- Commercial catch data
  - i. Total catch in weight
  - ii. Catch in number-at-age
  - iii. Mean weight-at-age
- Biological data
  - i. Weighting of spawning components
  - ii. Mean weight-at-age
  - iii. Maturity ogive (proportion mature-at-age)
  - iv. Natural mortality and proportion of F and M

- Survey data
    i. SSB estimate from egg surveys
    ii. Recruit abundance index from demersal trawl survey (no longer being used)

Currently, the western and southern egg survey provides the only fishery-independent data that are actually used for tuning the stock assessment models.

B.1. Commercial catch

Estimates of the magnitude (in tonnes) and precision of the unaccounted fishing mortality in the NEA mackerel fisheries suggest that, on average, total catch related removals are equivalent to between 1.6 and 3.4 times the catch. The variation could be due to:

- Fish that escape from fishing, but die, such as those that pass through the meshes and die
- Discards, slippage and high-grading not included in the ICA assessment
- Unreported catch throughout the time-series

(Simmonds 2007; ICES 2008a).

B.1.2. Total catch weight, catch in numbers and mean weight-at-age

Data Compilation

Commercial catch and associated sampling data are submitted to the stock coordinator each year by the national laboratories of the major mackerel catching nations. The 'exchange format' Excel worksheet was developed specifically for this purpose. In addition to catches and sampling data, information on misreporting, unallocated and discarded catch can also be submitted using this format. Data for nations with small (and generally unsampled) catches are retrieved by the stock coordinator from the Statlant database to complete the dataset for the year in question.

Once the complete dataset has been screened for errors, the stock coordinator will compile the data into the format required for input to the assessment. This involves the allocation of sample data to unsampled catches in order that all catches have an associated age structure. The process for allocating samples is rather ad-hoc with the stock coordinator selecting the appropriate samples (and their associated weighting) on the basis of the fleet definitions (gear), area and quarter.

Assessment Inputs

When the allocation exercise is complete the stock coordinator will format the data for input to the sallocl program (Patterson 1998). This involves the creation of 2 comma separated text files: disfad.csv (which contains the disaggregated dataset) and alloc.csv (which contains details of the sample allocations). The sallocl program produces a file sam.out from which the assessment inputs (catch number-at-age, catch weight-at-age and total catch weight) can be extracted. The sam.out, alloc.csv and disfad.csv files are stored in the working group archives folder.

Since 2007, the InterCatch web-based application has been used in parallel with sallocl. It is necessary to compile the data into an alternative format for upload to InterCatch. Comparisons of the sallocl and InterCatch output show good agreement between the two, with minimal differences.

B.1.2. Discards

Discarding of small mackerel has historically been a major problem in the mackerel fishery and was largely responsible for the introduction of the south-west mackerel box. In the years prior to 1994 there was evidence of large-scale discarding and slipping of small mackerel in the fisheries in Division IIa and Subarea IV, mainly because of the very high prices paid for larger mackerel (>600g) for the Japanese market. This factor was put forward as a possible reason for the very low abundance of the 1991 year class in the 1993 catches. Norway therefore introduced a special regulation to limit the slipping; this regulation was in force from 1988 to 2002. Anecdotal evidence from the fleet suggests that since 1994, discarding/slipping has been reduced in these areas. This is supported by the fact that the price for smaller fish have increased.

In some of the horse mackerel directed fisheries e.g. those in Subareas VI and VII mackerel is taken as by-catch. Reports from these fisheries have suggested that discarding may be significant because of the low mackerel quota relative to the high horse mackerel quota – particularly in those fisheries carried out by freezer trawlers in the fourth quarter. The level of discards is greatly influenced by the market price and by quotas.

With a few exceptions, since 1978 estimates of discards were provided to the Working Group for the areas VI, VII/VIIIa,b,d,e and III/IV. However, the Working Group considers the estimates for these areas as incomplete, e.g in 2007 discard data for mackerel were only provided by three nations: Scotland, the Netherlands and Germany. Countries providing discard estimates should be encouraged to also provide age based information so that the total stock removal may be more accurately estimated. No discards are available for the areas I/II/Vb and VIIIc/IXa.

B.2. Biological

B.2.1. Weighting of spawning components

The SSB estimates from the last egg surveys in the North Sea and the western/southern area are used.

B.2.2. Weight-at-age in stock

The mean weight-at-age in the stock is based on available samples from the area and season of spawning of each of the spawning components. The mean weights-at-age for the total stock are then calculated as weighted means, where the weighting is the egg survey based estimate of SSB in the three components. For a complete time series on mean weights-at-age in the three components and their relative weighting for the stock weights see the 2004 WHMHSA report (ICES 2005) and the WGWIDE reports since then.

Available samples from the commercial fishery have been supplemented by samples from the egg surveys. The egg survey samples have been applied to the year before the survey year as well as in the survey year. Since selectivity of the applied gear might affect the weight-at-age estimate; outlier samplings (e.g. from scientific vessels with small trawls and low engine power) are not used.

B.2.3. Maturity ogive (proportion mature-at-age)

The maturity ogive is based on the following information:

North Sea component: The present maturity ogive was constructed in 1984 on the basis of analysis of Norwegian biological samples from June-August 1960-81. This revealed that 74% of the 2 year old mackerel, which appeared in the catches, were sexually mature. By comparing fishing mortalities for II-group mackerel with the fishing mortalities for the III-group the year after, when they are fully recruited to the spawning stock, it seems that about 50% of the II-group mackerel are available to the fishery. Assuming that only the spawning component of the stock is available in the fishery, maturity ogive for the North Sea stock was estimated (ICES 1984).

Western component: The present maturity ogive was constructed in 1985 based on Dutch commercial and research vessel samples taken in April, May, June, July and August in Division VIa, south of 57"N, and Divisions VIIb,e,f,g,h,j during the period 1977-1984 (ICES 1985). The ogive was reviewed in 1997, but kept constant as before (ICES 1997b).

Southern component: Based on a histological analysis of mackerel samples collected during the 1998 Egg Survey (ICES 2000; Perez *et al*. 2000).

The proportion of mature mackerel-at-age for the total stock are calculated as the weighted mean each of the three components. The weighting is the egg survey based estimate of SSB in the three components. The maturity ogive is thus updated only when there has been an egg survey.

B.2.4. Natural mortality and proportion of F and M

Natural mortality (M) has been fixed at 0.15 for decades. The basis for this number can be found in (Hamre 1980). The first mackerel working group report where this value was given in was 1983 (ICES 1984).

To calculate proportions of F and M before spawning; the time of spawning each year was set to be the Julian day where 50% of the egg spawning had occurred. Subsequently, the time of spawning was taken as the mean of the annual estimates.

Interannual variation was observed to be low at the time of the benchmark in 2007. However, later estimates challenge this fixed assumption.

Natural mortality (M) was assumed to be constant through the year, so the proportion of natural mortality happening before spawning was readily calculated by multiplying M by the proportion of the year before the mean date of spawning.

Catch numbers were by quarter. The quarter 2 data partitioned in the observed catch before and after the mean date of spawning. Partial Fs were calculated using the output from the last assessment and the estimated catch was calculated using the catch equation. A proportion of F before spawning was then obtained by age and year and mean values calculated.

B.3. Surveys

B.3.1. Egg surveys

Two mackerel egg surveys have been performed for decades. Both surveys are presently only adding new information to these time-series every third year. One survey covers the western-southern spawning grounds while the other partly covers the spawning in the North Sea and Skagerrak (Figure A.3.2.1.).

Temporally each survey is split into several periods in order to cover the whole spawning season. Most countries use Gulf III or Gulf VII samplers with a mesh size of 250 µm. These samplers are torpedo-shaped with a flow meter, and may be encased or have an open design. Germany uses a Nackthai sampler, which has a similar design. Samples are collected using double oblique hauls at speeds of approximately 5 knots. Trawl samples of fish are collected in order to determine the sex ratio and the fecundity and atresia of female fish.

Mackerel eggs are sorted out from plankton samples. The eggs are staged and aged according the temperature at a five meter depth (Lockwood *et al*. 1981). Total annual egg production is then calculated by integrating all periods. Daily egg production (stage 1 eggs per m^2 per day) is measured and used to calculate a constant spatio-temporal coefficient of variation (CV). The SSB is estimated using information on sex ratio and fecundity of the females. The results are reported at the working group for mackerel egg surveys (WGMEGS).

B.3.2. International Bottom Trawl Survey

The CPUE index of mackerel recruits have previously been used in the mackerel assessment, however this was discontinued in the late '90s because of the poor performance of this survey (ICES 2000). Further analysis in 2008 concluded that calibration regression did not provide a more sensible prediction of recruitment than the approach of using the geometric mean of the recruitment series from VPA (ICES 2008a). The distribution of juvenile mackerel is very patchy, and abundance is highly variable between years. Although the survey data indicate presence and absence of young mackerel, they cannot be used to quantify spatial abundance accurately (Anon. 2009).

The time series used for this analysis was based on surveys carried out by France, Ireland, Portugal, Scotland and Spain (quarter 4 surveys) and by Scotland (quarter 1 surveys):

- 4th Quarter, age 0 mackerel from surveys 1985 – 2007
- 1st Quarter, age 1 mackerel from surveys 1985 – 2008
- 4th Quarter age 1 mackerel from surveys1985 – 2007
- A combined index using data from 4th quarter, age 0 mackerel and 1st quarter, age 1 mackerel from surveys 1985 – 2007.

Background on the IBTS survey

In the 1960s a number of countries around the North Sea started research vessel trawl surveys which were specifically aimed at the distribution and abundance of young herring (*Clupea harengus*); the International Young Herring Survey. Since 1974 the whole of the North Sea, Skagerrak and Kattegat have been surveyed annually in the first quarter of the year. It was soon realised that the survey also yielded valuable information for other fish species, such as cod and haddock, and so the objectives were broadened and the survey was renamed into the International Young Fish Survey (IYFS). A number of additional national surveys developed in a similar manner during the 1970s and 80s, these were mainly carried out in the third quarter.

In 1990 ICES decided to combine these surveys into the International Bottom Trawl Survey (IBTS) and over the years, co-ordinated them under the auspices of the IBTSWG with the aim of improving standardisation and collaboration between surveys. Prior to 1977 there was no standardisation of gear although all ships used bottom trawls with a small mesh cover. In 1977 ICES recommended that all ships should use a GOV trawl as specified by the Institute des Peches Maritimes, Boulogne. A detailed description of the net is to be found in the manual (ICES 2006a). The GOV trawl was gradually phased in, e.g. in 1979 only 3 vessels were equipped with the GOV trawl, but by 1983 all 8 nations were using this gear. It should be noted that although the gear is now standard, variations in the rigging exist between the various countries. This should be borne in mind when comparing results across the areas covered. The fishing method is also standardized and described in the manual (ICES 2006a). Fishing speed is 4 knots measured as trawl speed over the ground. In 1977 ICES also recommended that the duration of a tow should be reduced from an hour to half an hour with the catch data to be expressed in numbers per hour. All nations accepted this recommendation although it was a number of years before 30 minutes became the standard.

Two areas can be distinguished which differ in terms of the degree to which standardisation has been achieved: IBTS North Sea and IBTS western and southern areas. The North Sea IBTS are being carried out twice per year (1st and 3rd quarters) and in the period 1991-1996 also in 2nd and 4rd quarter. In 1994, the remit of the IBTSWG was extended to co-ordinate surveys in the western and southern areas (i.e. English Channel, Celtic Sea, Bay of Biscay, eastern Atlantic waters from the Shetlands to the strait of Gibraltar). While some attempts have been made in order to achieve a consensus on the choice of a standard gear, this was not achieved due to the variation in bottom types, and each country uses a different gear (GOV for France, Scotland and Ireland, BAKA for Spain and Norwegian Campelen Trawl for Portugal). Each country conducts surveys in adjacent areas with no overlapping, in various quarters of the year.

B.4. Commercial CPUE

None

B.5. Other relevant data

None

C. Historical Stock Development

A benchmark assessment for NEA Mackerel was carried out in 2007 by the working group on the assessment of Mackerel, Horse mackerel, Sardine and Anchovy (ICES 2007a). Following this benchmark investigation, the tool chosen for the assessment is ICA (Patterson and Melvin 1996). Since 2008, this method has been implemented in FLR (Kell, *et al* 2007) using the FLICA routine[1].

The ICA programme operates by minimising the following general objective function:

$$\sum \lambda_C \left(C-\hat{C}\right)^2 + \sum \lambda_I \left(I-\hat{I}\right)^2$$

which is the sum of the squared differences between the estimated and true value for the catches (separable model) and the tuning indices (catchability model).

The final objective function chosen for the stock assessment model was:

$$\sum_{a=0}^{12+} \sum_{y=Y-11}^{Y} \lambda_{ca} \left(\ln\left(C_{a,y}\right) - \ln\left(\hat{C}_{a,y}\right)\right)^2 + \sum_{y \in \{\mathrm{Y\_Egg}\}} \lambda_{MES} \left(\ln\left(q_{MES} S\hat{S}B_y\right) - \ln\left(MES_y\right)\right)^2$$

where

a and y	age and year
C	catch
$\hat{C}$	catch estimated by the separable model
$S\hat{S}B$	spawning stock biomass estimated by the model
MES	Mackerel Egg Survey index (biomass index) triennially
q_{MES}	catchability of mackerel egg survey
λ_{ca} and λ_{MES}	weighting factors for the catches and the survey
Y	Terminal year in the catch matrix
Y_Egg	Egg survey years in the separable period (e.g: 2001, 2004, 2007, 2010, etc.)

The λ_{ca} and λ_{MES} were defined to give the same weighting to the catch-at-age and to the survey for fitting the model. This was done by giving a weight of 0.33 to each year and age in the catch matrix (except for ages 0 and 1 which were down weighted by a factor 100 and 10 respectively). The weight given to the catch for a period of 3 years (interval between survey) is 3 years * 10 age classes * 0.33 = 10. Therefore, a weight of 10 was given to each survey value (setting in FLICA : index.var=0.1).

With ICA, it is possible to use a survey index related to the assessment year (AY), even if the last catch data available (and therefore the last population numbers-at-age estimated) are for the year previous to the assessment year (Y). In this case, the survi-

[1] In 2008, the assessment was run using both the old ICA software and FLICA and no difference was found between the output of the two methods.

vors are projected until the time of spawning and the corresponding SSB is calculated, assuming that maturity, weights and fishing mortality-at-age in the year AY are the same as in the year Y.

Note that the specific case of using the weighting described as above, results in giving a slightly higher weight to the survey than to the catch-at-age.

Implementation of the method is done by using R2.8.1, with the following FLR packages : FLCore2.2, FLAssess1.99-102, FLICA1.4-10, FLSTF1.99-1, FLEDA2.0, FLBRP2.0, FLash2.0 and the scripts developed to work with ICA : NEAMac Assessment.r, HAWG Common assessment module.r, HAWG Retro func.r, WriteIcaSum.r.

Input data types and characteristics:

Type	Name	Year range	Age range	Variable from year to year
Caton	Catch in tonnes	1972 - Y		Yes
Canum	Catch-at-age in numbers	1972 - Y	0-12+	Yes
Weca	Weight-at-age in the commercial catch	1972 - Y	0-12+	Yes
West	Weight-at-age of the spawning stock at spawning time.	1972 - Y	0-12+	Yes
Mprop	Proportion of natural mortality before spawning	1972 - Y	0-12+	No, fixed at 0.35
Fprop	Proportion of fishing mortality before spawning	1972 - Y	0-12+	No, fixed at 0.421
Matprop	Proportion mature-at-age	1972 - Y	0-12+	Yes
Natmor	Natural mortality	1972 - Y	0-12+	No, fixed at 0.15

Tuning data:

Type	Name	Year range	Age range
Survey	ICES Triennial Mackerel and Horse Mackerel Egg Survey	1992, 1995, 1998, 2001, 2004, 2007, 2010, etc.	Not applicable (gives SSB)

Model Options chosen according to the 2007 benchmark:

	Settings	Description
FLICA.control settings		
sr	FALSE	No stock-recruitment relationship used in the model
lambda.age	0.0033333, 0.033333, 0.33333, 0.33333, 0.33333, 0.33333, 0.33333, 0.33333, 0.33333, 0.33333,0.33333,0.33333,0.33333	Weighting matrices for catch-at-age; for aged surveys; for SSB surveys
lambda.yr	1 1 1 1 1 1 1 1 1 1 1 1	Relative weights by year
lambda.sr	0.1	weight for the SRR term in the objective function
index.model	linear	Catchability model for each survey
index.cor	FALSE	Are the age-structured indices correlated across ages
sep.nyr	12	Number of years for separable model
sep.age	5	Reference age for fitting the separable model
sep.sel	1.5	Selection on last true reference age
FLIndex settings		
index.var	0.1 for all years	Variance of the index (inverse of the weight given to each survey year)

Due to the high uncertainty in the recruitment estimates for the terminal year for the NEA Mackerel, the value estimated by ICA is arbitrarily replaced by the geometric mean of recruitment over the period 1972 to two years before the terminal year in the catch matrix (Y) (gmRec).

Due to the lack of data, the age for the plus group in the first years in the catch-at-age matrix increased until the year 1980 when it was set at age 12. For this reason Fbar4–8 cannot be correctly estimated when the plus group was smaller than 8 (before 1977), and SSB cannot be correctly estimated when the plus group was smaller than 12 (before 1980). Recruitment and total catch estimates are not affected by this problem.

D. Short-Term Projection

Deterministic short-term predictions are calculated using the stf routine in the FLAssess package. Projections are done three years ahead: assessment year (AY) to AY +2. For the intermediate year (= AY) an estimate of the catch is used (see below for more details). A range of management options for AY +1 are then tested.

In 2009 and 2010 the short term forecast was run in parallel comparing the stf routine with MDFP v.1a. The test showed that the two programs gave the same results.

The input data are detailed below:

Initial stock size:

Age 2 to 12+	the survivors at the 1st of January AY estimated by ICA are used as the starting populations in the prediction. The recruitment of age 0 (year class AY) and the abundance-at-age 1 (year class Y) are routinely revised due to the uncertainty of these estimates:
Age 0	gmRec is used for the recruitment-at-age 0 for Y-1 and Y in the predictions. ICA estimates of recruitment in Y and Y-1 are considered too uncertain be used in the geometric mean, because these year classes have not yet grown into the fishery. Recruitment in Y-2 is kept as estimated by ICA in order to be consistent with previous assessments, but changing this to a historically based value should be considered during next benchmark assessment.
Age 1	the abundance of the survivors-at-age 1 (in Y) is the geometric mean recruitment-at-age 0 brought forward 1 year by the total mortality-at-age 0 in the year before the assessment year.

Exploitation pattern:

The exploitation pattern used in the predictions was the separable ICA Fs, scaled to the F in the final year. As the model is fitted with 12 year separable period this is effectively the mean exploitation from Y-11 to Y inclusive.

The stf routine then uses the same relative selection pattern in AY to AY+2.

Maturity-at-age, weight-at-age in the catch and weight-at-age in the stock:

The 3 year average of Y-2 to Y was used.

Proportion of natural and fishing mortality occurring before spawning:

Use the constant values used for the whole period

Assumptions for the intermediate year:

The catch in the intermediate year (=AY) is taken as a TAC constraint. The catch is estimated from declared quotas modified by e.g. paybacks (e.g.EU COMMISSION REGULATION (EC) No 147/2007), discards, interannual transfers and expected overcatch.

Management Option Tables for the TAC year

The different management options for the catch in AY+1 are tested, according to the management plan implemented for NEA Mackerel since 2009:

- $Catch_{AY+1}$ = zero
- $Catch_{AY+1} = TAC_{AY} - 20\%$
- $Catch_{AY+1} = TAC_{AY}$
- $Catch_{AY+1} = TAC_{AY} + 20\%$
- $Fbar_{AY+1} = 0.20$
- $Fbar_{AY+1} = 0.21$
- $Fbar_{AY+1} = 0.22$

E. Medium-Term Projections

No medium-term projections

F. Long-Term Projections

No long term projections

G. Biological Reference Points

Limit points

Investigation using precautionary software (PaSoft, Cefas 1999) showed that there was no indications of reduced recruitment at biomasses above the lowest observed biomass of B_{loss} =1.67 Mt. A segmented regression fits a point of inflection to the same biomass point. On this basis B_{lim} is given the value of B_{loss}.

Yield per recruit evaluations using B_{loss} and assuming historic mean recruitment give an estimate of F_{loss} = 0.42. The value of F_{loss} is compatible with the proposed B_{lim} and on this basis F_{lim} is given the value of F_{loss}.

Precautionary reference points

Evaluations of precision of the assessment carried out during the management plan evaluations (ICES 2007a) show that the precision of F estimated in the assessment has a CV of 36%. The ICES procedure for evaluating precautionary reference points from limit points uses a formula based on the CV (ICES 2001) This formula gives a factor of 0.55 and an estimate of F_{pa} =0.23.

A similar evaluation of precision of the SSB (29%) would result in B_{pa} = 2.69 Mt, which exceeds the observed biomass during most of the period of the assessment of SSB (more reliable values since 1979). Due to the limited range of stock biomass and the precision of the assessment in the final year, it is therefore not possible to define both

B_{lim} and B_{pa} that lie within the observed range of biomass. Setting a B_{pa} outside the range of reliable observations is not thought to be appropriate. Given this situation it was deiced that B_{pa} should not be revised, until more information becomes available. Note that given B_{lim} the existing B_{pa} = 2.3 Mt does not reflect the assessment uncertainty. Under these circumstances it is not recommended to use B_{pa} as a management target but rather to follow one of the precautionary options under the proposed management plan.

	Type	Value	Technical basis
Precautionary approach	B_{lim}	1.67 million t	B_{loss}
	B_{pa}	2.3 million t	Trigger reference point used in the management agreed between Norway, Faroe, Islands, and the EU in 1999.
	F_{lim}	0.42	F_{loss}
	F_{pa}	0.23	F_{lim}*0.55 (CV 36%)
Targets	F_y	Between 0.20 and 0.22	2008 Management plan
	B_y	> 2.2 million t	

B_{pa} unchanged since 1998; target reference points changed in 2008; F_{pa}, F_{lim}, and B_{lim} revised in 2008

H. Other Issues

H.1. Management plans and evaluations

During 2007 and 2008 ICES provided a report on NEA mackerel long-term management (ICES 2008c) The content of the study was developed through a request from the European Commission and a series of meetings with representatives of Pelagic Regional Advisory Council (PRAC). The report was used by ICES to give advice in June 2008, which was presented to the PRAC in July 2008. Following this a request was made by the PRAC to provide information on tradeoffs between different management criteria, particularly concentrating on average catch, inter-annual change in catch and proportion of older fish. More runs were carried out with the software HCM with the same model conditioning and setting used to give ICES advice. These were used to give more detail in the region of greatest interest. The information on the methods used was given in (ICES 2008c).

An agreed management plan for NE Atlantic mackerel was finalised in October 2008. The management plan is as follows:

> The agreed record of negotiations between Norway, Faroe Islands, and EU in 2008 states that the long-term management plan shall consist of the following elements:
>
> 1. *For the purpose of this long-term management plan, "SSB" means the estimate according to ICES of the spawning stock biomass at spawning time in the year in which the TAC applies, taking account of the expected catch.*
> 2. *When the SSB is above 2,200,000 tonnes, the TAC shall be fixed according to the expected landings, as advised by ICES, on fishing the stock consistent with a fishing mortality rate in the range of 0.20 to 0.22 for appropriate age groups as defined by ICES.*
> 3. *When the SSB is lower than 2,200,000 tonnes, the TAC shall be fixed according to the expected landings as advised by ICES, on fishing the stock at a fishing mortality rate determined by the following:*
>
>   *Fishing mortality F = 0.22* SSB/ 2,200,000*
> 4. *Notwithstanding paragraph 2, the TAC shall not be changed by more than 20% from one year to the next, including from 2009 to 2010.*
> 5. *In the event that the ICES estimate of SSB is less than 1,670,000 tonnes, the Parties shall decide on a TAC which is less than that arising from the application of paragraphs 2 to 4.*
> 6. *The Parties may decide on a TAC that is lower than that determined by paragraphs 2 to 4.*
> 7. *The Parties shall, as appropriate, review and revise these management measures and strategies on the basis of any new advice provided by ICES*

From (NEAFC 2008)

ICES consider the agreement to be consistent with the precautionary approach. However, the management plan does not specify measures that would apply under poor stock conditions that preclude further evaluation.

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Stock Annex 2: B – Western Horse Mackerel

Quality Handbook ANNEX: B – Western Horse Mackerel

Stock specific documentation of standard assessment procedures used by ICES.

Stock	Western Horse Mackerel (Divisions IIa, IIIa-west, IVa, Vb, VIa, VIIa-c, VIIe-k, VIIIa-e)
Working Group:	Working Group on Widely Distributed Stocks
Date:	29 August 2011
Revised by	WGWIDE, 02 September 2011

A. General

A.1. Stock definition

Stock Identity

For many years, ICES considered horse mackerel (*Trachurus trachurus*) in the northeast Atlantic to be separated into three stocks. Prior to the conclusion of the project HOMSIR in 2003, this separation was motivated mainly on the basis of temporal and spatial distributions of the fishery and observed egg and larval distributions (ICES 2008/ACOM:13), but early on was also supported by information from acoustic and trawl surveys, and from parasite infestation rates in horse mackerel (ICES 1989/Assess:19, 1990/Assess:24, 1991/Assess:22). The southern stock was defined as that found in the Atlantic waters of the Iberian Peninsula, the North Sea stock in the eastern English Channel and North Sea area, and the western stock on the northeast continental shelf of Europe, stretching from the Bay of Biscay in the south to Norway in the north.

The occurrence of the large 1982 year class in the eastern part of the North Sea during the latter half of 1987, which resulted in the commencement of a sizeable Norwegian fishery for horse mackerel in the third and fourth quarters from the late 1980s, led to questions about the distribution of the North Sea stock (ICES 1989/Assess:19). A combination of commercial catch and bottom trawl survey data indicated that western horse mackerel had a similar migration pattern to mackerel, so that outside the spawning season bigger fish migrate north to reach the northern North Sea in the latter half of the year (Iversen *et al*. 2002). Differences were also noted in the development of the fishery and in the parasite infestation rates of horse mackerel in Divisions IIa and IVa compared to Divisions IVb-c and the English Channel, suggesting that fisheries in these two areas were exploiting fish from two different spawning areas (ICES 1990/Assess:24, 1991/Assess:22). Therefore, since 1989 ICES has allocated catches taken in Division IIa and in Division IVa (in later years only during the third and fourth quarters of the year for IVa, and including the western part of Division IIIa) to the western stock (ICES 1989/Assess:19).

A Study Group on stock identity held in 1992 (ICES 1992/H:4) found that, although there were clear centres of egg production, there were no major discontinuities in the distribution of eggs between the western and southern areas, bringing into question the separation between these stocks (ICES 1992/Assess:17). It was hoped a tagging program launched in Spain and Portugal in 1994 (ICES 1995/Assess:2), and two studies conducted in 1997 using allozyme differentiation and morphometric characteristics (ICES 1998/Assess:6) would shed further light on stock identity, but none of the tags were ever recovered (ICES 1996/Assess:7, 1997/Assess:3, 1998/Assess:6, 1999/ACFM:6, 2000/ACFM:5, 2001/ACFM:06), and neither study provided a basis for changing the stock separation previously defined (ICES 1998/Assess:6).

Further refinements of the definitions of stock units were made based on the results from HOMSIR (EU-funded project: QLK5-CT1999-01438), which integrated a variety of approaches to investigate horse mackerel stock identification (ICES 2005/ACFM:08, Abaunza *et al*. 2008). The project investigated the stock structure of horse mackerel from a holistic point of view within the western, southern, North Sea and Mediterranean areas. It included various genetic approaches (multilocus allozyme electrophoresis, mitochondrial DNA analysis, microsatellite DNA analysis and single stranded conformation polymorphysm SSCP analysis), the use of parasites as biological tags, body morphometrics, otolith shape analysis and the comparative study of life history traits (growth, reproduction and distribution). The project concluded in June 2003, and some of the main results from this project, which are of relevance to the western stock, were as follows (ICES 2005/ACFM:08):

i) Horse mackerel from the west Iberian Atlantic coast can be distinguished from the rest of the Atlantic areas.

ii) In the Atlantic Ocean, the northern boundary of the so called "southern stock" ought to be revised, and accordingly, the southern boundary of the so called "western stock". The body morphometrics and the otolith shape analysis joined the northwest of the Iberian Peninsula (North Galicia) to the areas located more to the North in the Atlantic Ocean, Bay of Biscay and Celtic Sea. On the other hand, the genetic results from SSCP associated the northwest of Iberian Peninsula to the Portuguese sampling sites. These differences between the techniques suggested that North Galicia may correspond to a transition area between two possible stock units. Therefore, it was proposed to move the actual boundary of the "Southern" and "Western" stocks from Cape Breton Canyon (southeast of Bay of Biscay) to the northwest of Iberian Peninsula (Galician coasts) and specifically to Cape Finisterre at 43º N latitude, which could be considered also as a boundary for certain hydrographic features, like the influence of North-Atlantic Central Water (Fraga *et al.*, 1982).

iii) Parasites and body morphometrics indicated that horse mackerel in the North Sea could constitute a stock well differentiated from the rest of adjacent Atlantic areas.

iv) Horse mackerel along western European coasts, from the northwest of Spain to Norway, seem to be a unique stock. This definition is very similar to that previously used for the "western stock", except that, based on results from HOMSIR, the north coast of the Iberian Peninsula should also be included. Neither the SSCP results nor the parasite composition study showed any contradiction with this definition. Anisakid parasite species composition is homogenous throughout this area. Otolith shape analysis and body morphometrics include the sampling sites from this area in the same cluster, showing a great similarity in morphometric characteristics.

v) However, the population structure in the western European coasts could be more complicated and more research is needed to clarify the migration patterns within the Northeast Atlantic Ocean. This is especially relevant to the boundary areas between the North Sea Stock and the Western stock (Northern North Sea and English Channel).

Therefore, in many ways, results from the HOMSIR project largely supported ICES perceptions of stock units. Based on findings from the project, ICES now includes Division VIIIc as part of the distribution area of the western horse mackerel stock. The boundaries for the different stocks are given in Figure B.1.

Allocation of catches to stock

Based on spatial and temporal distribution of the horse mackerel fishery the catches were allocated to the western stock as follows:

Western stock: Quarters 3&4 only: Divisions IIIa (west), IVa
All Quarters: Divisions IIa, Vb, VIa, VIIa-c,e-k and VIIIa-e.

The reason why catches from only the western part of Division IIIa are allocated to the western stock is that these catches are taken in the third and fourth quarter, and are often taken in the neighbouring area of catches from the western stock in Division IVa. ICES is not sure if catches in Divisions IVa and IIIa during the first two quarters are of western or North Sea origin. Usually this is a minor problem because the catches in these areas during this period are small. However, in 2006 and 2007, relatively larger catches, 2 600 and 2 100 tons, were taken in Division IVa during the first half of the year and these catches were allocated to the North Sea stock.

A.2. Fishery

Germany and the Netherlands have a directed trawl fishery and Norway a directed purse seine fishery for horse mackerel. Spain and Portugal have both directed and mixed trawl and purse seine fisheries. In earlier years most of the catches were used for meal and oil while in later years most of the catches have been used for human consumption.

The Dutch and German fleets operated mainly west of the Channel, in the Channel area, and in the southern North Sea. The Spanish and Portuguese fleets operated mainly in their respective waters. Ireland fished mainly west of Ireland and Norway in the north eastern part of the North Sea.

A.3. Ecosystem aspects

Western horse mackerel have a long spawning season with a peak in late spring/early summer (Abaunza *et al.*, 2003). They spawn in the Bay of Biscay and southwest of the British Isles (indicated as the “juvenile area” in Figure B.1). Age and length distributions from around the British Isles suggest that, as for northeast Atlantic mackerel (*Scomber scombrus*), the largest fish tend to travel farthest and may reach areas around the Shetland Islands, the Norwegian coast, and the northern North Sea by September (Eaton, 1983).

Three species of genus Trachurus: *T. trachurus*, *T. mediterraneus* and *T. picturatus* are found together and are commercially exploited in NE Atlantic waters.

Following the Working Group recommendation (ICES 2002/G:06), special care has been taken to ensure that catch and length distributions and numbers at age of *T. tra-*

churus supplied to the Working Group did not include *T. mediterraneus* and *T. picturatus*. Spain provided data on *T. mediterraneus* and Portugal on *T. picturatus*.

T. mediterraneus is almost exclusively landed in ports of the Cantabrian Sea in the north of Spain. The fishery for *T. picturatus* takes place in the southern part of Division IXa and in Subarea X. The annual landings of *T. mediterraneus* show substantial variability, ranging from about 500t to 7,000 tones. Since 2004 there has been a decrease in landings reaching the lowest level in 2007.

B. Data

B.1. Commercial catch

Catch in numbers

Since 1998 there has been an increase in age readings compared with previous years, which has improved the quality of the catch at age matrix for western horse mackerel. Catches from some countries were converted to numbers at age using adequate samples from other countries. The procedure has been carried out using the specific software for calculating international catch at age (Patterson WD presented in ICES 1999/ACFM:6). Usually catch at age data are provided by the Netherlands, Norway, Ireland and Spain. In some years also Germany and Scotland have provided such data. Therefore adequate sampling has never been conducted in all fishing areas during the fishing season.

Discards

Over the years, only one, and in later years two, countries have provided data on discards, so that the estimated amount of discards are not representative for the total fishery. During recent years only the Netherlands and Germany have provided discard data. No data on discards were provided during 1998-2001. Based on the limited data available it is impossible to estimate the amount of discard in the horse mackerel fisheries.

B.2. Biological

Mean weight at age in the stock

The mean weight at age is based on mature fish sampled from Dutch freezer trawlers in the first and second quarter in Divisions VIIj,k. In some years there are only data from Division VIIj. Often there are no data for two years olds and then they are given a constant weight of 0.085 kg. The mean weight by age groups in the stock and in the catches were lower than usual in 2001, but returned to normal since 2002.

Maturity ogive

Due to difficulties in estimating a maturity ogive (ICES 2000/ACFM:5, 2000/G:01) the working group has been unable to update the maturity ogive annually. Therefore the same maturity at age has been used since 1998.

Natural mortality

The natural mortalities applied in previous assessments of western horse mackerel are summarised and discussed in ICES (1998/Assess:6). The natural mortality is uncertain but probably low. ICES currently applies $M=0.15.year^{-1}$.

B.3. Surveys

Egg survey estimates of biomass

The Mackerel and Horse Mackerel Egg Survey takes place triennially with the participation of Portugal, Spain, Scotland, Ireland, The Netherlands, Norway and Germany. It is not possible to convert the horse mackerel egg production to SSB since horse mackerel is considered an indeterminate spawner.

In general the quality and reliability of the egg surveys are good. In contrast to 2007 the 2010 results display a bimodal distribution which is almost identical both in shape and scale to that seen in 1998 with peak spawning occurring in periods 3 and 5 and a significant decline in production during period 4

Since 2003 the ICES working group WGMEGS has held an egg identification and staging workshop prior to the survey. This permits a harmonisation of egg identification and realised fecundity in mackerel as well as spawning rates in horse mackerel across the participating institutes. These activities led to an improvement in the quality of the estimate.

Even when the survey coverage is good, WGMEGS concludes that while the starting of the spawning event is fully covered for mackerel and horse mackerel, the surveys end too early to adequately cover the end of spawning in the northern areas for both mackerel and horse mackerel, and in the southern area (south of 47°N) for horse mackerel.

Bottom trawl surveys

Bottom trawl surveys are carried out in a systematic and standardized way through the Northeast Atlantic. They cover a significant part of the western horse mackerel distribution area and are carried out mainly during the autumn. These surveys are coordinated in the International Bottom Trawl Surveys Working Group (IBTSWG, ICES 2009/RMC:04) with the main objective of obtaining an index of recruitment for the most important commercial fish species. Horse mackerel is a pelagic species, but its behaviour is closer to that of a demersal species than the rest of typical pelagic species. The IBTS could therefore provide information on horse mackerel distribution, catch rates and length distributions. Taking in to consideration the problems with the abundance index used in the western horse mackerel assessment, it is useful to consider the surveys under IBTSWG in order to analyse whether they could provide an index of recruitment or abundance for western horse mackerel.

Data from the bottom trawl survey carried out in autumn in the Cantabrian Sea and Galician coasts (North of Spain, Division VIIIc) were analysed in relation to horse mackerel. This survey is not used in the assessment because it covers only a small part of the western horse mackerel stock, but it provides valuable information on horse mackerel dynamics. Length distributions show a gap in length range 18-23cm that could be related to the particular exploitation pattern of this species. Juveniles are more abundant in the eastern part of the Cantabrian Sea, although the depth strata <120m, in which the young horse mackerel are also distributed, and are very poorly sampled in the Galician coasts. The recruitment in 1994 appeared to be strong in the data series (ICES 2008/ACOM:13). The evolution of the cohorts through the data matrix compiled from this survey indicated poor information on mortality. This could be due to migration to and from other areas, especially the French continental shelf (Murta *et al.*, 2008; Velasco *et al*. 2008). The information provided by this survey will be combined with the results of other bottom trawl surveys carried out in adjacent areas. Traditionally age 0 has been adopted as the recruitment age for horse mackerel in this survey; nevertheless the use of age 1 as a proxy for recruitment may be more appropriate. The years before 1997 have been revised to account for the change in the strata of the sampling design adopted in 1997 (Velasco *et al*. 2008).

The French bottom trawl survey (EVHOE-WIBTS-Q4) covers the Bay of Biscay (French continental shelf) and part of the Celtic Sea. It is carried out in autumn and it is directed at demersal resources. Information on horse mackerel distribution and length distributions are available. The survey is carried out during the recruitment season, and juveniles form the majority in the catches.

It might be useful for the WG to collect all information available about horse mackerel from other bottom trawl surveys carried out in the distribution area of the western horse mackerel stock (e.g. IBTS).

Acoustic surveys

Horse mackerel data from the French acoustic PELGAS surveys are available as independent information on the western horse mackerel stock (ICES 2006/LRC:18). This multidisciplinary survey covers Divisions VIIIa and VIIIb during spring, collecting information on spatial distribution and length distribution. Revised survey estimates were presented in 2008 (Massé et al. WD presented in ICES 2008/ACOM:13).

Horse mackerel data from the Spanish acoustic PELACUS-Q4 surveys are available as independent information on the western horse mackerel stock. This multidisciplinary survey covers Divisions VIIIc and IXa (north) during spring. In some years the survey is extended to the south of Divisions IXa (north) and VIIIb. Information on distribution and abundance estimates are available since 1997, but the biomass estimates of the historical series were calculated considering Divisions IXa (north) (actually belonging to the southern stock) and VIIIc (western stock) until 2006 .The information will be split up by stock in the future.

B.4. Commercial CPUE

Information on effort and catch per unit effort is only available from the southern limit of the stock distribution area. Since Division VIIIc became part of the western stock in 2004 (ICES 2005/ACFM:08), the bottom trawl fleet operating in the western part of Division VIIIc (north of the Galician coast) is exploiting the western stock. This area represents a very small part of the western horse mackerel stock and therefore the fleet has not been used in the assessment.

The activity of this bottom trawl fleet is considered as mixed fisheries in which different métiers can be distinguished. Due to the assumption that CPUE is proportional to abundance, it is important that any other factors that may influence CPUE are removed from the index. The process of reducing the influence of these factors on CPUE is commonly referred to as standardizing the CPUE. Therefore, it is possible to present in the future a new revised and standardized version of this CPUE series following the métiers classification, with the objective of obtaining a more reliable CPUE at age series.

B.5. Other relevant data

None

C. Historical Stock Development

Model used: SAD (linked separable-ADAPT VPA assessment model).

Software used: AD Model Builder, version 2008 (ICES 2008/ACOM:13). The source code is freely available in ICES folders.

Description of SAD

The SAD model has been used by the working group since the 2000 meeting. The WGMHSA Review Group of ACFM in 2005 stated that the SAD model, purposely designed to assess this stock, was the most appropriate tool. A detailed description of the SAD assessment model and rationale for its use is provided in ICES (2003/ACFM:07) and De Oliveira *et al*. (2010). Figure B.2 presents an illustration of the model structure and the "free" parameters estimated by maximum likelihood (i.e. those estimated directly), and the following table summarises its main features.

A summary of the main features of the SAD model used for the assessment of western horse mackerel:

Model	SAD
Version	2009 Working Group (WGWIDE) (ICES 2008/ACOM:13)
Model type	A linked separable VPA and ADAPT VPA model, so that different structural models are applied to the recent and historic periods. The separable component applies to the most recent period, while the ADAPT VPA component applies to the historic period. Model estimates from the separable period initiate a historic VPA for the cohorts in the first year of the separable period. Fishing mortality at the oldest true age (age 10) in the historic VPA is calculated as the average of the three preceding ages (7-9, ignoring the 1982 year-class where applicable), multiplied by a scaling parameter that is estimated in the model. In order to model the directed fishing of the dominant 1982 year-class, fishing mortality on this year-class at age 10 in 1992 is estimated in the model.
Data used	Egg production estimates, used as relative indices of abundance and catch-at-age data (numbers). Weights-at-age in the stock and maturity-at-age vary temporally, but are assumed to be known without error. Natural mortality and the proportions of fishing and natural mortality before spawning are fixed and year-invariant. Fecundity data are potential fecundity vs. fish weight data for the years 1987, 1992, 1995, 1998, 2000 and 2001, and a realised fecundity 'prior' distribution for 1989, with a mean and CV derived from a normal distribution in log-space, which covers (with a 95% probability) the range of realised fecundity values reported by Abaunza *et al*. (2003).
Selection	The separable period assumes constant selection-at-age, and requires estimation of fishing mortality age- and year-effects (the former reflecting selectivity-at-age) for ages 1-10 and the final x years for which catch data are available (x being the length of the separable period). Selectivity at age 8 is assumed to be equal to 1. The length of the separable period should be balanced against the precision of model estimates and whether there is any indication, from the log-catch residuals, that the separable assumption no longer holds.
Fishing mortality assumptions	The fishing mortality at age 10 (the final true age) is equal to the average of the fishing mortalities at ages 7-9 (ignoring the 1982 year-class where applicable) multiplied by a scaling parameter estimated within the model. The fishing mortality at age 10 in 1992 (applicable to the 1982 year-class) is estimated separately. The plus-group fishing mortality is assumed equal to that of age 10.
Estimated parameters	The parameters treated as "free" in the model (i.e. those estimated directly) are: (1) Fishing mortality year effects for the final four years for which catch data are available; (2) Fishing mortality age effects (selectivities) for ages 1-10 (except for selectivity at age 8 which is set to 1); (3) scaling parameter for fishing mortality at age 10 relative to the average for ages 7-9 (ignoring the 1982 year-class where

	applicable); (4) fishing mortality on the 1982 year-class at age 10 in 1992; (5) realised fecundity parameter, relating realised fecundity to potential fecundity, and therefore also relating estimated SSB to the egg production estimates; (6) potential fecundity parameters (intercept and slope), relating potential fecundity to fish weight.
Plus-group	A dynamic pool is assumed (plus group this year is the sum of last year's plus group and last year's oldest true age, both depleted by fishing and natural mortality). The plus group modelled in this manner allows the catch in the plus group to be estimated, and making the assumption that log-catches are normally distributed allows an additional component in the likelihood, fitting these estimated catches to the observed plus-group catch.
Objective function	The estimation is based on maximum likelihood. There are five components to the likelihood, corresponding to egg estimates, catches for the separable period, catches for the plus-group, potential fecundity vs. fish weight, and realised fecundity. The variance of each component is estimated, apart from that associated with realised fecundity for which a CV is input.
Variance estimates / uncertainty	Estimates of precision may be calculated by several methods, the simplest (based on the delta method) being used for results shown.
Program language	AD Model Builder (Otter Research Ltd)
References	Description in Working Group reports, De Oliveira *et al.* (2010).

In 2005 the WG identified aspects of the assessment that warranted further exploration, which included whether there was additional information, particularly in relation to fecundity, that would allow scaling the model (ICES 2006/ACFM:08). Fecundity data (both actual data and estimates from the literature) was subsequently identified for inclusion in the model. Further investigation revealed evidence that potential (i.e. standing stock) fecundity per gram increases with fish weight (ICES 2002/G:06), and total realised fecundity would be expected to follow the same pattern. In line with this argument, the stock average fecundity would have increased as the 1982 year-class matured (as individuals gained weight) and then decreased when the strong year class was fished out. Ignoring these effects could lead to biased population estimates.

The SAD model explicitly incorporates and directly fits potential and realised fecundity data as functions of fish weight, with separate parameters for the two types of fecundity data, thus placing the estimation of fecundity parameters in a self-consistent framework. The model uses a realised fecundity 'prior' distribution (mean=1847 eggs per gram spawning female, CV=0.287), which is derived from a normal distribution, in log-space, which covers (with a 95% probability) the range of realised fecundity values reported by Abaunza *et al*. 2003 (1 040-3 280 eggs per gram spawning female). This allows the incorporation of a realistic level of uncertainty about realised fecundity.

The likelihood function used in SAD is as follows (ICES 2008/ACOM:13):

$$
\begin{aligned}
-\ln L = {} & \tfrac{1}{2} \sum_{y \in Y_{egg}} \left\{ \frac{\left(\ln N_{egg,y} - \ln(\hat{N}_{egg,y})\right)^2}{\hat{\sigma}^2_{egg}} + \ln\left[2\pi\hat{\sigma}^2_{egg}\right] \right\} \\
& + \tfrac{1}{2} \sum_{y=2003}^{2007} \sum_{i=1}^{10} \left\{ \frac{\left(\ln C_{y,i} - \ln \hat{C}_{y,i}\right)^2}{\hat{\sigma}^2_{sep}} + \ln\left[2\pi\hat{\sigma}^2_{sep}\right] \right\} \\
& + \tfrac{1}{2} \sum_{y=1983}^{2007} \left\{ \frac{\left(\ln C_{y,11+} - \ln \hat{C}_{y,11+}\right)^2}{\hat{\sigma}^2_{11+}} + \ln\left[2\pi\hat{\sigma}^2_{11+}\right] \right\} \\
& + \tfrac{1}{2} \sum_{y \in Y_{pfec}} \sum_{j=1}^{J_y} \left\{ \frac{\left(\ln f^p_{y,j} - \ln \hat{f}^p_{y,j}\right)^2}{\hat{\sigma}^2_{pfec}} + \ln\left[2\pi\hat{\sigma}^2_{pfec}\right] \right\} \\
& + \tfrac{1}{2} \left\{ \frac{\left(\ln \bar{f}^r_{1989} - \ln \hat{\bar{f}}^r_{1989}\right)^2}{\sigma^2_{rfec}} + \ln\left[2\pi\sigma^2_{rfec}\right] \right\}
\end{aligned}
$$

where i represents age, $N_{egg,y}$ the egg production estimates, $C_{y,i}$ catch-at-age, $f^p_{y,j}$ potential fecundity for sample j in year y, and $\bar{f}^r_{1989}$ population-mean realised fecundity for 1989. Model estimates are shown with "^" and data without.

The model estimates egg production as follows:

$$\hat{N}_{egg,y} = \sum_i q_{fec}(a_{fec} + b_{fec} w_{y,i})\, B^{sp}_{y,i}\, s^f$$

where i represents age, q_{fec} the realised fecundity parameter, a_{fec} and b_{fec} the potential fecundity parameters, $w_{y,i}$ mean weights-at-age in the population, $B^{sp}_{y,i}$ SSB-at-age, and s^f the female sex ratio.

Potential fecundity is estimated as follows:

$$\hat{f}^p_{y,j} = a_{fec} + b_{fec} w_{y,j}$$

where $w_{y,j}$ are the sample weights for sample j of year y associated with the potential fecundity data $f^p_{y,j}$, and a_{fec} and b_{fec} are as before.

Population-mean realised fecundity is estimated as follows:

$$\hat{\bar{f}}^r_y = \frac{q_{fec}}{\sum_i N_{y,i} m_{y,i}} \sum_i N_{y,i} m_{y,i} (a_{fec} + b_{fec} w_{y,i})$$

where i represents age, $N_{y,i}$ population numbers-at-age, $w_{y,i}$ mean weights-at-age in the population, $m_{y,i}$ maturity-at-age, and q_{fec}, a_{fec} and b_{fec} as before.

The "free" parameters estimated directly in the model are:

1) Fishing mortality year effects (F_y) for the separable period;

2) Fishing mortality age effects (S_a, the selectivities) for ages 1-10 (excluding age 8, which is set at 1);

3) scaling parameter (F_{scal}) for fishing mortality at age 10 relative to the average for ages 7-9 (ignoring the 1982 year-class where applicable);

4) fishing mortality on the 1982 year-class at age 10 in 1992 ($F_{92,10}$);

5) realised fecundity parameter (q_{fec}), relating realised fecundity to potential fecundity, and therefore also relating SSB to egg production; and

6) potential fecundity parameters (a_{fec} and b_{fec}), relating potential fecundity to fish weight

Natural mortality (constant at age and by year at 0.15), maturity-at-age, stock weights-at-age and the proportions of F and M before spawning (0.45), are assumed to be known precisely.

Model Options chosen

For 2011, the separable window was 6 years long (2005-2010). Decisions about whether to shift the window along (keeping it 6 years long) or whether to extend the window (keeping the starting date at 2004) depend on whether the log-catch residuals show the separable assumption to continue to hold or not.

Input data types and characteristics:

Type	Name	Year range	Age range	Variable from year to year Yes/No
Caton	Catch in tonnes	-	-	Not used
Canum	Catch at age in numbers	1982-present	0-11+	Yes
Weca	Weight at age in the commercial catch	-	-	Not used
West	Weight at age of the spawning stock at spawning time.	1982-present	0-11+	Yes
Mprop	Proportion of natural mortality before spawning			No
Fprop	Proportion of fishing mortality before spawning			No
Matprop	Proportion mature at age	1982-present	0-11+	Yes (but constant since 1998)
Natmor	Natural mortality	-	-	No

Tuning data (data appearing in likelihood function):

Type	Name	Year range	Age range
Western Horse Mackerel egg survey	Total egg production estimates	1983, 1989, 1992,… (every third year)	-
Separable period catch-at-age	Separable catch-at-age	2005-present (but depends on length of separable window)	1-10
Plus-group catch	Plus-group catch	1982-present	11+
Potential fecundity	Potential fecundity vs. fish weight data	1987, 1992, 1995, 1998, 2000 and 2001	-
Realised fecundity	Total realised fecundity, based on Abaunza et al. (2003)	1989	-

D. Short-Term Projection

Software used: MFDP version 1a (Multi Fleet Deterministic Projections)

Initial stock size: Stock numbers from the assessment

Recruitment: At the 2010 working group recruitment estimates for input to the short term forecast were based on the geometric mean of the estimated time series for the period 1983 to 2008. There is no indication that a large recruitment similar to that of 1982 will enter the stock.

Maturity: The proportion mature for this stock is assumed constant over the years. The maturity ogive used in the short term forecast is the same as the ogive used in the assessment for 2009.

F and M before spawning: Spawning is assumed to take place in April/March.

Weight at age in the stock: Weight at age in the stock are the average of the last three years weight at age estimates in the catch for periods 1 and 2 in areas VIIj.

Weight at age in the catch: Weight at age in the catch are the average of the last three years weight at age estimates in the catch for all periods and all areas.

Exploitation pattern: This is based on F in the final year, where the final year of data is calculated from the most recent assessment. The assessment assumes a fixed selection from 2005 to the final year of data.

Natural Mortality: Natural mortality is assumed to be 0.15 across all ages.

E. Medium-Term Projections

A medium-term forecast is not conducted for western horse mackerel because a management plan is in place.

F. Long-Term Projections

Long-term projections are not carried out for western horse mackerel.

G. Biological Reference Points

The stock is characterised by infrequent, extremely large recruitments.

Reference point	B_{lim}	B_{pa}	F_{lim}	F_{pa}	$F_{0.1}$
Value	1.4 mill t	1.8 mill. t			0.13
Basis	Biomass that produced the extraordinary 1982 year class	B_{lim}* exp(1.645* σ), with σ= 0.16.	Not defined	Not defined	Yield per recruit (ICES, 2010/ACOM:15)

Biomass reference points

It could be assumed that the likelihood of a strong year class appearing would decline if stock size were to fall below the stock size at which the only such event has been observed. The WG therefore considers the biomass that produced the extraordinary 1982 yc as a good proxy for B_{lim}. This follows the rationale of SGPRP 2003 (ICES 2003/ACFM:15), proposing to use the stock size in 1982 for B_{lim}. Evaluation of precision of the assessment shows that the CV in SSB is 15%. The ICES procedure for evaluating precautionary reference points from limit points uses a formula based on the CV (ICES 2001/ACFM:11). This formula gives a factor of 30% and an estimate of B_{pa} = 1.8Mt.

Fishing mortality reference points

The age range used in the calculation of mean F was changed in 2003 from $F_{4\text{-}10}$ to $F_{1\text{-}10}$ to include the ages exploited in both the adult and juvenile fisheries. The management plan currently in place is not based on F (see section 5). There are indications that the assumed natural mortality (0.15) might be too high. However, there is insufficient data to estimate M.

MSY reference points

At WGWIDE 2010 (ICES 2010/ACOM:15) deterministic and stochastic equilibrium analyses were carried out using the 'plot-MSY' software (ICES 2010/ACOM:54) to review the 2010 Fmsy value for the western horse mackerel stock. Stock-recruit pairs from the period 1983-2010, as estimated from the most recent SAD assessment of the stock, were used together with 5-year averages of selectivity, weight and maturity at age , F refers to the mean for ages 1 – 10. Three stock recruit relationships were reexamined, Ricker, Beverton-Holt and the segmented regression ('smooth hockey stick'), and yield-per-recruit (YPR) analyses were also done. For the stochastic analyses, uncertainty (CVs) in the biological and fishery parameters at age were used to create alternative fits to the stock-recruit relationships (N=1000).

The results show a very poor Beverton and Holt fit (Figure 5.7.1.1) to the stock and recruit data. The majority of stochastic stock-recruit model fits fell out of the range of the deterministic fit to the data, and thus it can be concluded that the stock-recruit form is unclear and not suitable for the data and the level of uncertainty associated with the parameters. Given the lack of any clear patterns in the stock-recruit data, a smooth segmented regression model fit, while uncertain around the origin, could provide the most cautious fit to the data. The deterministic segmented regression fit has a shallow slope to the breakpoint, hence the estimated value of Fcrash associated with this function is low. However this slope is determined by very few data points and is therefore poorly estimated. The value for Bmsy is at the breakpoint in the segmented regression, hence Fmsy is estimated to be the same as Fcrash (Table 5.7.1.1). The uncertainty with regards to the slope at the origin makes this stock-recruitment function unsuitable as a basis for advice on Fmsy. The Ricker stock recruit relationship fits the data best, and the median of the stochastic fits is in close agreement with the deterministic fit. If this stock recruit relationship is considered to be biologically reasonable, this function could be used in the calculation of Fmsy. However, there is a very large uncertainty around the fit to the data, as can be seen in the spread of potential stochastic fits. This results in a very high CV around the estimate of Fmsy, again making this function unsuitable as the basis of advice on the selection of Fmsy.

Given the poor fits to stock and recruitment data, a yield-per-recruit analysis remains the conducted (Figure 5.7.1.2). The stochastic analysis shows a well defined Fmax. The uncertainty around this value which results from the associated CVs in the input data and believed to be realistic, provide a potential range of values for consideration of a proxy for FMSY. However, the point estimate of Fmax= 0.22 is close to Fcrash. Alternatively, F0.1= 0.13 is consistent with the findings of the management plan evaluation. This evaluation by simulation showed that in the absence of extraordinary year classes F around 0.1 would result in a risk less than 10% of depleting the stock. On that basis F0.1 = 0.13 is considered a more suitable candidate for Fmsy than Fmax. It is proposed that F0.1 = 0.13 be used as a proxy for Fmsy for this stock. The SSB that produced the extraordinary 1982 year class (1.8Mt) is proposed as MSY Btrigger.

Reference point	**MSY $B_{trigger}$**	**F_{MSY}**
Value	1.8 mill. t	0.13
Basis	B_{lim}	**$F_{0.1}$**

H. Other Issues

None.

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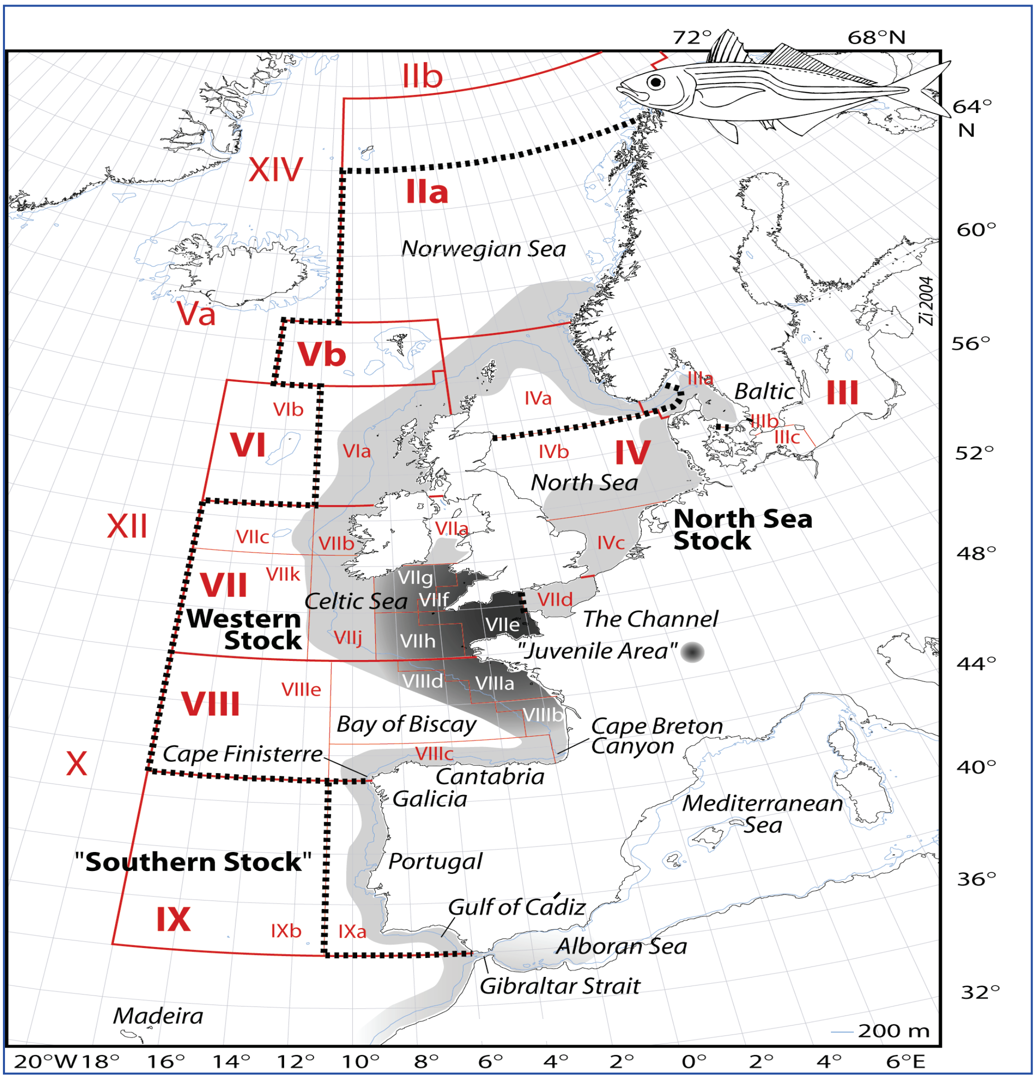
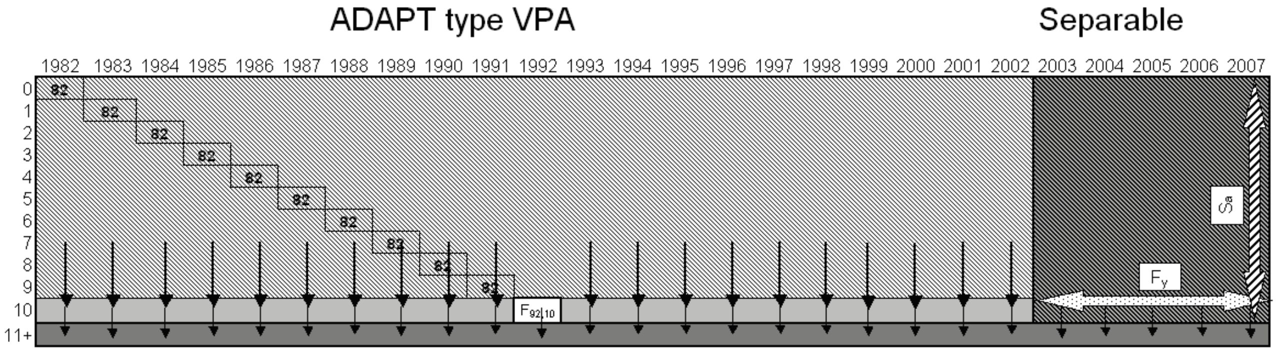


a)

Figure B.1: Distribution of Horse Mackerel in the Northeast-Atlantic: Stock definitions as used by ICES (ICES CM 2005/ACFM:08). Note that the "Juvenile Area" is currently only defined for the Western Stock distribution area – juveniles do also occur in other areas (like in Div. VIId). Map source: GEBCO, polar projection, 200m depth contour drawn.



Model estimated parameters

1	F_y	Year effects in separable period fishing mortalities
2	S_a	Age effects in separable period fishing mortalities (with value at age 8 set to 1)
3	$F_{92,10}$	Fishing mortality on the 1982 year class at age 10 in 1992
4	F_{scal}	The scaling parameter which adjusts fishing mortality at age 10 relative to the avererage of ages 7 - 9
5	q_{egg}	Realised fecundity parameter, relating realised fecundity to potential fecundity, and therefore also relating estimated SSB to the western horse mackerel egg production time series
6	a_{fec}, b_{fec}	Potential fecundity parameters (intercept and slope), relating potential fecundity to fish weight

Figure B.2. Western Horse Mackerel. An illustration of the SAD model structure used for the assessment of the Western horse mackerel stock and the "free" parameters estimated by maximum likelihood.

Stock Annex 2C – Norwegian Spring Spawning Herring

Quality Handbook	ANNEX:C – Norwegian Spring Spawning Herring

Stock specific documentation of standard assessment procedures used by ICES.

Stock	Norwegian Spring Spawning herring
Working Group:	WGWIDE
Date:	13 November 2013 of last revision
Revised by	WGWIDE

A. General

A.1.1 Stock definition

The Norwegian spring spawning herring (*Clupea harengus*) is the largest herring stock in the world. It is widely distributed and highly migratory throughout large parts of the NE Atlantic during its lifespan. Formally, the description of the Norwegian spring spawning herring stock is not linked to specific areas and the ICES advice applies to all areas where it occurs. By far the majority of the stock occurs in Divisions IIa,b Va,b and XIVa. Juveniles of the stock have their nurseries in Division Ia. In some years, small amounts of Norwegian spring spawning herring can be found in adjacent areas mixing with other herring stocks.

It is a herring type with high number of vertebrae, large size at age, large maximum size, different scale characteristics from other herring stocks and large variation in year class strength. The herring spawns along the Norwegian west coast in February-April. Large variations in the north-south distribution of the spawning areas have been observed through the centuries. The larvae drift north and northeast and distribute as 0–group in fjords along the Norwegian coast and in the Barents Sea. The Barents Sea is by far the most important juvenile area for the large year classes, which form the basis for the large production-potential of the stock. Some year classes are in addition distributed into the Norwegian Sea basin as 0–group. Examples of this are the 1950 and 2002 year classes. Most of the young herring leave the Barents Sea as 3 years old and feed in the north-eastern Norwegian Sea for 1–2 years before recruiting to the spawning stock. Large year classes typically mature at a higher mean age due to density dependent distribution and growth. However, exceptions occur and the 2002 year class is a large year class, which has shown quick growth and a relatively early maturation. Juveniles growing up in the Norwegian Sea grow faster than those in the Barents Sea and mature one year earlier. With maturation the young herring start joining the adult feeding migration in the Norwegian Sea. The feeding migration starts just after spawning with the maximum feeding intensity and condition increase occurring from late May until early July. The feeding migration is in general length dependent, meaning that the largest and oldest fish perform longer and typically more western migrations than the younger ones. After the dispersed feeding migration the herring concentrate in one or more wintering areas in September-October. These areas are unstable and since 1950 the stock has used at least 6 different wintering areas in different periods. During the 1950s and 1960s they were situated east of

Iceland and since around 1970 in Norwegian fjords. In 2001–2002 a new wintering area was established off the Norwegian coast between 69º30′N and 72ºN and in 2007\2009 no herring was observed in the fiords in winter. After wintering, the spawning migration starts around mid January.

Norwegian spring spawning herring is one the few stocks for which data have been collected over a very long period. Figure A.1.1.1 shows the dynamics of the stock in the past century indicated by assessments which go back to 1907.

A.1.2. Migration

A characteristic feature of this herring stock is a very flexible and varying migration pattern. The migration is characterised as relatively stable periods and periods characterised by large changes occurring at varying time intervals. The changes may or may not be correlated between the major distribution areas: Spawning, feeding and wintering. At present we see a period of large changes in both the wintering and feeding area. Until about 2002 the bulk of the adult herring wintered in fjords in northern Norway. The 1998 and 1999 year classes were expected to enter the fjords around 2002, but were instead observed wintering off the coast in the ocean off Vesterålen/Troms, between 69º30′N–72ºN. This continued in the years to come and in 2005 also the 2002 year class was observed wintering in the same area. During these years, the amount of older herring wintering in the fjords has decreased rapidly and during the winter 2007 and 2008 no herring was observed in the fjords. The survey covering the oceanic wintering area in November have shown a strong decrease in the biomass in the wintering stock in the area, indicating that may be a third and so for unknown wintering area could be under establishment somewhere else. Such a development is supported by the western feeding distribution in recent years, and the fact that the return migration of the smaller herring feeding in the west could be too long compared with comparable return migration distances observed in earlier periods. It is also supported by the fact that the international survey in May did not show any such negative trend in the stock.

In May the herring is migrating westward into the Norwegian Sea to start feeding and main concentrations are found in the central part of this area. In July the herring are spread out over a wide area feeding around the fringes of the Norwegian Sea, particularly in the northern and western region, while almost no herring are observed in the central region.

During the autumn in the period 2004–2008 Norwegian spring spawning herring has been caught as bycatch in smaller concentrations in catches of Icelandic summer spawning herring off the Icelandic east coast. This feature is probably linked to the western movement of the south-western summer feeding area. It is not known whether Norwegian spring spawning herring are wintering in this area.

A.2. Fishery and management

The fishery is regulated and carried out by the Coastal States. The TAC is set by the Coastal States and derived from an agreed long term management plan. The Coastal States also agree on the allocation of the TAC into national quota. The Coastal States involved are the European Union, Faroe Islands, Iceland, Norway and the Russian Federation. The fishery is carried out all year round by purse seines and pelagic trawlers. The catches are used as well for reduction purposes and human consumption. The traditional fishing pattern follows the clockwise migration pattern of the herring. Changes in the migration pattern have occurred in the past and consequently also leading to changes in the fishery, following the fish. The migration pattern, together with environmental factors, was mapped in 2008 during the ICES PGNAPES (Planning Group on Northeast Atlantic Pelagic Ecosystem Surveys) investigations (ICES 2008/RMC:05).

Due to limitations by some countries to enter the EEZs of other countries the fisheries do not necessarily depict the distribution of herring in the Norwegian Sea and the preferred fishing pattern of the fleets given free access to any zone.

Most of the catches consist of herring only and discarding is absent or very low. In recent years increasing amounts of bycatch of mackerel are reported on the traditional fishing grounds, pointing to a change in de distribution of mackerel.

A.3. Ecosystem aspects

Norwegian spring spawning herring is a straddling stock. Juveniles and adults of this stock form an important part of the ecosystems in the Barents Sea, the Norwegian Sea, and the Norwegian coast. Herring has an important role as food resource to higher trophic levels (e.g. large fish, seabirds, and marine mammals), but also as a consumer of zooplankton in the Norwegian Sea and capelin larvae in the Barents Sea. A high stock size will therefore have positive effects on its predators, but the effects on other pelagic fish stocks feeding in the Norwegian Sea such as blue whiting and mackerel may be negative due to competition for food.

Changes in the herring migration in the first decade of the 21th century have led to an increased proportion of the population feeding in Faroese and Icelandic waters. The growth of these herring is faster than those feeding further east and north.

Not much information is available on the impact of the herring fishery on the ecosystem. The fishery is entirely pelagic. There is little quantitative information on the by-catches in the fisheries for herring but these are thought to be small. Therefore unintended effects of the fishery on the ecosystem are probably small or absent. Since herring is a major source of food for some populations of other species, overfishing of the herring stock could affect these populations. This is presently not the case since the herring stock is very abundant and is exploited at a low rate.

B. Data

B.1. Commercial catch

B.1.1. Nominal catch

The catches used in the assessment are the catches provided by the Working Group members.

B.1.2. Catch at age

From each country participating in the herring fishery exists a data delivery sheet containing at minimum information about total catch in tons by quarter of the year and ICES area. If the fleet has taken samples then catch in numbers by age, mean weight at age and mean length at age for each quarter of the year and ICES area are provided. Catch in tonnes by ICES rectangles and quarters are also reported. These sheets are combined into one file, the so called 'disfad' file. None sampled catches have then to be allocated to sampled ones. To do so positions of the catches by fleet are plotted, to see where the fleet was operating. Mean weights and mean lengths behind the sampled catches are also plotted. On the basis on these inspections allocations are done. Then the program SALLOC (ICES 1998/ACFM:18) is used to calculate the total international catch in numbers. Output from SALLOC is total catches in numbers by age as well as by quarters and areas. INTERCATCH is only used for archiving the data used in the assessment.

B.1.3. Weight at age of the catch

Annual weight at age of the catch originate from national sampling programmes of the commercial catches. They are provided by most fishing nations each year on a quarterly basis. The weight at age of the catch used in the assessment is the average of the different nations weighted over the associated catch numbers. Mean weights by age in the catch by age is also output from SALLOC.

B.1.4. Length at age of the catch

Mean length by age in the catch is calculated the same way as mean weight at age of the catch. It is not used in the assessment Mean length by age in the catch is also output from SALLOC.

B.2. Biological parameters

B.2.2. Weight at age of the stock

Up to 2008 weight of age of the stock was taken from the Norwegian survey in the wintering area (reference). The survey has stopped in 2008. From 2009 onwards weight at age of the stock is taken from commercial catches taken in the same area and period as the Norwegian survey. In 2010 sampling of data on weight at age in the stock in this period and area has increased to improve the precision of the estimates.

B.2.3. Natural mortality

B.2.3.1. History of the use of M in the assessment

The back ground of the natural mortality used in the assessment has been reviewed in the 2008 benchmark assessment of this stock. By scanning through the Working Group reports from 1990 to 2007 it was noticed that different values had been used for natural mortality at age through the years. In some years an additional mortality at age had been applied because of a disease. But taken directly from the 1997 WGNPBW-report (ICES 1997): "Values of natural mortality assumed by the Working Group previously (ICES 1996/ASSESS:14) for ages 3 and older were 0.16 for the years 1950 to 1970 and 0.13 for the years 1971 and subsequently. In the previous assessment of this stock it was assumed (on the basis of observations of many diseased and dying fish in catches) that the fish of the 1987 cohorts and older had suffered a higher natural mortality in the years 1991 to 1994. An additional disease-induced natural mortality of 0.1 was assumed. However, interim studies (Patterson, WD 1997; Tjelmeland WD 1997) directed at estimating disease-induced mortality have failed to provide compelling evidence for values above zero. Attempts to estimate natural mortality from tagging information (Hamre, WD 1997; Patterson, WD 1997a; Tjelmeland, WD 1997) were highly consistent with values in the range 0.13 to 0.16, but the Working Group did not consider that this parameter could be estimated with sufficient precision to justify a discrimination between levels of 0.13 and 0.16. Consequently it was decided to predicate the assessment model estimates on an arbitrarily-chosen M=0.15

for ages 3 and older, and no attempt was made to include additional disease-induced mortality in the maximum likelihood assessment model."

This value M=0.15 has been used for ages 3 and older since the assessment in 1997 (for all years) until the assessment made in 2005 (ICES 2005). Then a value of 0.5 was used for the plus group (16+) and was used until 2007. This increase of M was done in order to get the SSB at low values in the collapsed phase in the 1970s. It caused only a slight decrease of the SSB in the recent years (ICES 2005).

From 2008 onwards age 15 is used in the assessment as a plus group and a value of M=0.15 is used.

In the Working Group report from 1992 (ICES 1992) a comparison of acoustic estimates for year classes 1983-1985 and 1988, and the same year classes as 3 year old (VPA) gave an average annual M=0.88, so M=0.9 was used for ages 0-2.

For ages 0-2 then the following is stated in the report from 1997 (ICES 1997): "Values of natural mortality for juvenile fish (ages 0-2) used by the Working Group in 1996 were 0.9 for all years in historic VPA, but for forecasting purposes values of 1.56 for age 1 and 0.54 for age 2 were used for the 199-1995 year classes. These values were based on an unpublished Ph.D. Thesis by de Barros (1995); this work was not available for evaluation by the Working Group, and hence it was decided to retain the assumption of M=0.9 for ages 0 to 2 in all years. This value is consistent with the mean of de Barros' estimates." This value of M=0.9 is still used in the present assessments for ages 0-2.

B.2.3.1. M used in the present assessments

In the benchmark assessment, the natural mortality M=0.15 was used for ages 3 and older and M=0.9 was used for ages 0–2 in all years from 1988 onwards.

B.2.4. Maturity at age

In 2010 WKHERMAT evaluated the information on maturity for this stock. This work was planned to be carried out in the benchmark assessment in 2008 but at that time this information was not available. WKHERMAT proposed to used maturity o-gives based on back calculation of rings on the scale. This information provided a long time series which is reproducible. WGWIDE introduced this times series in the 2010 assessment.

B.2.4.1. Maturity data used in the assessments prior to 2010

The text in italics in the following paragraphs in this section is old text and no longer valid

Except for the year class 2002, the proportion mature at age used in assessment has generally been the same during the last ten years (Table B.2.4.1).

The growth rate of the 2002 year class has been higher than usually seen in large year classes of this stock. One reason for this is that a large part of the juveniles stayed in the Norwegian Sea as juveniles, favouring quicker growth than in the Barents Sea, which is the area where juveniles normally are distributed.

The proportion mature of this year class was calculated from samples collected during the surveys in the wintering area in November (before spawning) and in the Norwegian Sea in May (after spawning). The proportion of fishes in maturation stage 3 or larger (fish to spawn) in November 2005 was used as a first proxy to the proportion maturing. The proportion matur-

ing according to these data was 0.85. The proportion in stages >5 (spent) in May was used as a proxy for the proportion having spawned. The proportion having spawned according to these data was 0.92. Based on these observations and calculations 0.9 was adopted as proportion mature of the 2002 year class at age 4. Based on this 1.0 instead of 0.9 was adopted as proportion mature of the 2002 year class at age 5. All other year classes in the later years were set at the standard 0.3 at age 4, 0.9 at age 5 and 1.0 at age 6 both in the assessment and predictions.

The Working Group has accepted the present values for the use in the assessment but considers that there is a need to validate the presently assumed values in particular for the most recent years. The proportion mature at age used in assessment is based on various surveys carried out many years ago and is not always well documented. The Working Group acknowledged the potential problem of obtaining random samples of proportion mature at age from survey for this stock due to the different catchability of mature and immature fish of the same age groups caused by spatial segregation. An alternative method for estimating proportion mature at age was proposed to the Working Group. This method involves back-calculation of proportion mature at age from fully matured year classes and is based on work done by Engelhard et al. (2003) and Engelhard and Heino (2004). The Working Group found this approach interesting, but decided to explore it further before any decision should be taken regarding using it in assessment. The Working Group recommends that effort should be put into updating estimates on proportion mature at age from recent years with this method and compare it with data on direct measurements on proportion mature at age from the May survey during the period since 1997 when this survey was assumed to cover the entire stock. This work will be done by IMR but has not completed yet. Based on this, an evaluation will be done and may lead to revisions of the maturity 0-gives in the past.

The surveys in the wintering area in November (reference) have stopped in 2008. From 2008 onwards only information is available from the May survey (reference). In 2009, WGWIDE has recommended to adjust (increase) the sampling for maturity in this survey in the May survey to ensure sufficient coverage (spatial and by age) of the data.

The old time series is not longer used and is presented in the stock annex.

B.2.4.2. Maturity data used in the assessments from 2010 onwards (inserted in 2011)

In 2010 a Workshop (WKHERMAT)[1] was held to evaluate existing maturity at age data. The Workshop was held because data on maturation were not available and considered in the benchmark assessment in 2008. The work of the Workshop therefore concludes the benchmark process. Three sources of maturity information were considered. The three different data sources were: a) maturity ogive used in assessment, b) survey data on maturity staging collected during surveys 4 and 5 and c) back-calculated maturity ogive using Gulland's method. In addition, data on maturity cycle in Norwegian spring spawning herring were presented and guidelines for sampling of maturity data were discussed in accordance with PGCCDBS.

The maturity matrix used in the ICES assessment goes back to 1907. Documentation on the source of information and the justification of changes is almost absent and the lack of documentation is a general problem in this data set. The data cannot be repro-

[1] Report of the Workshop on estimation of maturity ogive in Norwegian spring spawning herring (WKHERMAT). 1-3 March 2010 Bergen, Norway. ICES CM 2010/ACOM:51 REF. PGCCDBS

duced because the sources are unknown and most changes which have been made in the past cannot be explained.

The May surveys may potentially provide data to construct updated maturity ogives for the most recent years. The surveys indicate that most (but not all) herring in the Norwegian Sea are mature and most (but not all) herring in the Barents Sea are immature. However, the time series is short and there are some problems. For the age groups which occur both in the Norwegian Sea and Barents Sea, quantitative information on annual abundance is required for a the calculated weighted average maturity representative for the stock in both areas combined. The available information on the distribution of these age groups in not very reliable because there appear to be differences in the catchability in the survey between the Norwegian Sea and the Barents Sea. This needs to be addressed further before data from the survey can be used for maturity ogive estimations.

The back calculation data set indicates that maturation of ages 3, 4 and 5 has varied considerable over time and that maturation of large year classes is slower than for others. This applies to a lesser extend to the 2002 year class. However, the estimates for this year class are suggesting that at least a correction needs to be considered in the maturation assumed for this year class in previous assessments by ICES. WKHERMAT considered the data set derived by back calculation as a suitable potential candidate for use in the assessment because it is conceived in a consistent way over the whole time period and can meet standards required in a quality controlled process. However, the back calculation estimates cannot be used for recent years. Since the surveys do not provide suitable data at the moment, assumptions have to be made for recent year classes.

WGWIDE considered the results of WKHERMAT in 2010 and adopted the maturity o-gives derived from back calculation of scales for the historical time period (years 1950-2007) in the assessment. WGWIDE recommends that this data set remains updated in future years. For the years after 2007 for which no data are available from this method (including the years considered in the forecast) the following default maturity o-gives will be assumed. For 'normal' classes (average, median and weak year classes), an average maturity at age will be assumed from the periods 1983-2007 from the back calculation data set excluding the strong year classes 1983, 1991, 1992, 1998, 1999, 2002. For year classes which are considered strong, preliminary estimates will be assumed to be the average of the recent strong year classes 1983, 1991, 1992, 1998, 1999, 2002 in the data set.

The default maturity o-gives used for 'normal' and strong year classes are given in the text table below.

AGE	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
normal yc	0	0	0	0	0.4	0.8	1	1	1	1	1	1	1	1	1	1
strong yc	0	0	0	0	0.1	0.6	0.9	1	1	1	1	1	1	1	1	1

A comparison of the old and new time series in given in the WKHERMAT report. The maturity ogives used in previous assessments are given in Table B.2.4.1. The maturity ogives used in the present assessment are presented in the WGWIDE report.

Except for those periods where strong year classes enter the stock, the revision of the maturity at age matrix affects has little effect on the estimates of SSB in the historical time series. Because strong year classes show slower maturation, the SSB estimates in periods where strong year classes recruit in the stock have been revised downwards compared to previous ICES assessments.

B.2.4.3 Terminal F calculation (added 2013)

The preliminary assessment in 2013 following the 2008 benchmark revealed the same strong retrospective patterns as have been observed since assessment year 2010. However, adding the latest catch statistics and survey information lead to unexpectedly large changes in the perception of the stock, particularly in the earlier period of the assessment time series (see WD Skagen 2013 and WGWIDE 2013 report) that were considered to be out of proportion. As a result of the data exploration WGWIDE 2013 implemented an updated algorithm for calculating the terminal F-values for last age classes where no data supporting the estimate of terminal stock numbers was available.

Because some of the year classes are very small, there are no data to estimate the terminal stock numbers in the VPA (before 1982, 1984 – 1988, 1995 and 2000 – 2001). In the 2008 benchmark the derivation of the terminal fishing mortalities for those of these year classes that had reached oldest true age, was defined as derived from the terminal F the year before and fishing mortalities at younger ages, with the standard procedure in TASACS. However, because of the sensitivity of this method to noise particularly in the estimates of older age groups, Skagen (WD to WGWIDE 2013) suggested a new algorithm for this derivation. The new algorithm for deriving the terminal stock numbers for these year classes assumes a fixed ratio between F at oldest age and average F in the year, which is equivalent to assuming a fixed selection at oldest age. Similar method is used in the assessment model ICA, and in the separable option in TASACS. The ratio is taken from the selection parameters, as the selection at oldest age relative to the mean over the ages 5 - 13. There is no standard way to estimate that ratio. However, a sensitivity analysis showed that the the exact ratio used has only a minor influence on the estimated numbers in the earlier time period and none on the latest part of the times series. Values between 1.1 and 1.7 give comparable results. The ratio between the terminal F and the average F over ages 5-13 calculated for all the years where terminal F is estimated is 1.3 (excluding all F = 0), and this was applied in the 2013 assessment. B.3. Surveys

A number of surveys on this stock have been carried out in the Norwegian Sea and Barents Sea to estimate the size of the stock, its age composition or the recruitment to the stock. Some of the surveys have stopped but data are still used in the assessment The surveys and its potential use are described in the sections below.

B.3.1. Survey 1. Norwegian acoustic survey on spawning grounds in February/March

Background and status

The survey has been carried out since 1988 but not in every year. The survey will not be carried out after 2008.

Use of this survey in stock assessment

The age groups 5–15+ have been used in the assessment for the years 1994 to 2005. After this year the survey has not been used in the assessment. The reason for this being that the survey was carried out very earlier and before the herring had reached the spawning grounds, with the possibilities of herring emerging the spawning grounds also through other routes than those covered in the survey.

Results

Results can be found in Table B.3.1.1 and Figure B.3.1.1.

B.3.2. Survey 2. Norwegian acoustic survey in November/December

Background and status

The survey has been carried out by Norway since 1992 in the Norwegian fjords where the adult herring winter. Since 2003 also the oceanic areas north of Lofoten/Vesterålen has been included in the survey to take account of changes in the wintering area. The fjordic coverage was ceased during the winter 2007/2008 because the herring had totally left the fjords.

Results

In 2007 the RV Johan Hjort carried out an acoustic survey in the oceanic wintering area in northern Norway (Figure B.3.2.1). The results of this survey are shown in Table B.3.2.1. This survey covers the known wintering area of the mature part of the stock. The survey gave a very low biomass estimate due to unknown reasons. One possible explanation is that a new wintering area is building up somewhere else. This has so far not been confirmed and remains an open question.

Use of this survey in stock assessment

Given the large changes in the wintering pattern of herring and the possibility of a third and undescribed wintering area, it was decided not to use this survey for the period following the new wintering pattern of the herring in the assessment. The survey will not be continued by Norway and will not be carried from 2008 onwards.

B.3.3. Survey 3. Norwegian acoustic survey in January

Background and status

This survey was carried out by Norway in the fjords in the period 1991–1999.

Results

The results of the survey in the wintering area in January can be found in Table B.3.3.1.

Use of this survey in stock assessment

Although the survey series has ended, the data are still used in the assessment. The age groups 5–15+ from 1991 to 1999 are currently used.

B.3.4. Survey 4 and 5. International ecosystem survey in the Nordic Seas

Background and status

The international ecosystem survey in the Nordic Seas is aimed at observing the pelagic ecosystem, focusing herring, blue whiting, zooplankton and hydrography. The survey, carried out since 1995, is coordinated by the ICES PGNAPES (ICES CM 2009/RMC:06) and is a cooperative effort by Faroes, Iceland, Norway, Russia, and the EU (Denmark, Germany, Ireland, The Netherlands, Sweden and UK). This trawl-acoustic survey supplies the most important time series for the assessment of NSSH and also a time series for young blue whiting in the juvenile areas.

Results

The age-disaggregated time-series of abundance for the Barents Sea and Norwegian Sea are presented in Table B.3.4.1. and Table B.3.4.2.

Survey covering the entire stock during its migration on the feeding grounds. An example of the coverage of the survey (2009) is given in Figure B.3.4.1.

Use of this survey in stock assessment

From the area west of 20°E the full time series of age groups 4 and older in survey 5 are used for the assessment. Survey 4 in the area east of 20°E covering the Barents Sea has been used in the final assessment from 2005 onwards. The survey supplies the recruitment for age groups 1 and 2 in the assessment. No data exist for 2003 and 2004 in this survey. The data for 2008 are not used. The data for survey 4 are also used for estimating recruitment in RCT3.

B.3.5. Survey 6 and 7. Joined Russian-Norwegian ecosystem autumn survey in the Barents Sea

Background and status

The survey consists of a trawl survey catching 0–group herring amongst other species and an acoustic survey estimating one and two year old herring. In 2001, the Working Group decided to include data on immature herring obtained during the Russian-Norwegian survey in August-October in estimating the younger year classes in the Barents Sea.

Results

The results from these surveys on 0–group herring are given in Table B.3.5.1. The results for the 1 to 3 age groups are given in Table B.3.5.2. The youngest age groups (0+

to 3+) of the Norwegian spring spawning herring stock are found in the Barents Sea at irregular intervals. It is difficult to access the stock size during autumn, due to various reasons. The age groups 1 to 3 are found mixed with 0–group herring and are difficult to catch in the sampling trawl used in this survey. The stock size estimates of herring are therefore considered less reliable than those for capelin and polar cod. An example of the distribution of young herring is shown in Figure B.3.5.1. An example of the distribution of 0–group herring is presented in Figure B.3.5.2.

Use of this survey in stock assessment

The indices of age groups 1 and 2 of survey 6 are used in the assessment with the exception of 2002.. The index of survey 7 is used for the estimation of recruitment by RCT3.

B.3.6 Survey 8 Norwegian herring larvae survey on the Norwegian shelf

Background and status

A Norwegian herring larvae survey has been carried out on the Norwegian shelf since 1981 during March-April. The objectives of the survey are to map the distribution of herring larvae and other fish larvae on the spawning grounds on the Norwegian shelf and to collect data on hydrography, nutrients, chlorophyll and zooplankton. The larval indices are used as indicator of the size of the spawning stock. Two indices are available from this survey.

Results

Two larvae indices are available from this survey and presented in Table B.3.6.1. Index 1 represents the total number of herring larvae found during the survey. Index 2 represents the back-calculated number of newly hatched larvae assuming 10% daily mortality. Examples of the distribution of the herring larvae are given in Figure B.3.6.1.

Use of this survey in stock assessment

The "Index 1" is used in the assessment as representative for the size of the spawning stock except for the years 2003 and 2009 (Table B.3.6.1).

B.3.7 Survey 9 International ecosystem summer survey in Nordic Sea

Background and status

This ecosystem survey initiated in 2004 by Norway and have since then been gradually expanded in geographical coverage and scientific complexity (e.g. Nøttestad and Jacobsen 2009). In 2009, and 2010, the survey coverage was expanded further with participations of vessels from Iceland and the Faroese in addition to two vessels from Norway. The main objective of the survey is to study abundance, spatiotemporal distribution, aggregation and feeding ecology of Northeast Atlantic mackerel, Norwegian spring-spawning herring, blue whiting and other pelagic species in relation to oceanographic conditions, prey communities and marine mammals. Two different types and independent abundance estimates for herring can de derived from the survey, an acoustic estimate, and swept area estimate from pre-defined surface trawl stations.

Results

The survey was extended very much in 2009, so the acoustic estimates for herring since then (Table B.3.7.1) are not comparable to the previous estimates. An example of the coverage of the survey (2010) is given in Figure B.3.7.1.

Use of this survey in stock assessment

The time series where the herring stock has been covered adequately goes only back to 2009. Thus, the survey has not been used directly in the assessment of NSSH.

B.4. Commercial CPUE

No commercial CPUE data are used in the assessment.

B.5. Other relevant data

With the exception of 1999, 2001 and 2005, tagging has been carried out annually between 1975 and 2007. In 2007 Norway has decided to discontinue the tagging program in 2008 and in future years.

The use of the tagging data in the assessment was discontinued since 2006 due to a low number of recaptures. This comes as a result of too low tag density in the stock given the high stock size and amount of fish screened for tags.

C. Historical Stock Development

Model used: VPA

Software used: TASACS, version

Model Options chosen:

Analyses are restricted to the years 1988-present

Age range for the analyses is 0-15+

Natural mortality is assumed at 0.9 for ages 0, 1 and 2 and 0.15 for all older ages.

Assumed fraction of fishing mortality and natural mortality for each of the age-structured surveys

Fleet 1	Fleet 2	Fleet 3	Fleet 4	Fleet 5	Fleet 6	Fleet 7
0.17	0.91	0.17	0.41	0.41	0.70	0.70

Catchability for the age structured surveys independent of age for ages >4

Exploration of the survey data is carried out in order to investigate whether the survey contributes information to the assessment or whether there is no or little in-formation in the survey data. In the case where the survey contributes mostly noise to the assessment it is not included in further exploration and in the final assessment. In addition, when conflicting information appears between different surveys, it is attempted, as far as possible, to use expert knowledge about the performance and known problems of the different surveys, to resolve conflicts by excluding the data that were considered the least reliable.

Rather than excluding information from the survey on a subjective basis, criteria are set for exclusion. These are set based on the general observations and the analysis of comparisons of the consistency within and between the surveys. The following criteria are used for exclusion of data:

1) Data outside the range of years and age windows selected by previous WG have also been excluded in the present assessment. Such as incomplete survey coverage of the stock of survey not completed due to other reasons.
2) Survey data of poor year classes with mostly noise are excluded. This is for instance the case for year class 1995 in all surveys.
3) Reject ages where the analysis of consistency between and within surveys indicate severe problems. For instance for survey 1, the conclusion from the correlation analyses is not to use information at ages older than age 11.
4) If there is a conflict between data from different surveys, discard the data where known problems with the survey indicates that these are the least reliable. This applied in particular to conflicts between survey 2 and survey 5, where survey 2 indicated a rapid decline in the stock and survey 5 a more gentle decline. Since representative sampling of old fish in survey 2 is a known problem, caused by vertical segregation in the wintering areas in the Lofoten fjord, the survey 2 data are ignored and the survey 5 data used. at ages above 10 years.
5) If there are internal inconsistencies in the old ages in a survey (mismatch between abundance at young and old age), the old ages are ignored.
6) No zero values are used.

All observations still included were given equal weight, except for the catches at the youngest ages, where the following weightings, relative to the standard weighting of 1.0 are used:

Age 0	0.001
Age 1	0.001
Age 2	0.01
Age 3	0.1

Input data types and characteristics:

Type	Name	Year range	Age range	Variable from year to year Yes/No
Caton	Catch in tonnes	1988-last data year	0-15+	Yes
Canum	Catch at age in numbers	1988-last data year	0-15+	Yes
Weca	Weight at age in the commercial catch	1988-last data year	0-15+	Yes
West	Weight at age of the spawning stock at spawning time.	1988-last data year	0-15+	Yes
Mprop	Proportion of natural mortality before spawning	1988-last data year	0-15+	Yes
Fprop	Proportion of fishing mortality before spawning	1988-last data year	0-15+	Yes
Matprop	Proportion mature at age	1988-last data year	0-15+	Fixed in later years
Natmor	Natural mortality	1988-last data year	0-15+	Yes

Tuning data:

Type	Name	Year range	Age range
Tuning fleet 1	Norwegian acoustic survey on spawning grounds in February/Match	1995-2005	5-15+
Tuning fleet 2	Norwegian acoustic survey in Nov/Dec	1992-2001	4-14+
Tuning fleet 3	Norwegian acoustic survey in January	1991-1999	5-15+
Tuning fleet 4	International Ecosystem survey in the Nordic Seas and	1991-last data year	1-2
Tuning fleet 5	International Ecosystem survey in the Nordic Seas	1991-last data year	4-15+
Tuning fleet 6	Joined Russian-Norwegian ecosystem autumn survey in the Barents Sea	2000-last data year	1-2
Tuning fleet 7	Joined Russian-Norwegian ecosystem autumn survey in the Barents Sea	2000-last data year	0
Tuning fleet 8	Norwegian herring larvae survey	1981-last data year	

The stock summary from the 2009 assessment is included in table 9.4.5.3. The TASACS assessment covers the period 1988 to the present. The data prior to 1988 originate from the Sea Star assessment carried out in 2007?D. Short-Term Projection

Model used: Deterministic short-term projection, with management option table presenting average F-values for age 5-14 weighted over population numbers at the start of the year.

Software used: Excel spread sheet. No approved and formal tested software exists. A spreadsheet was developed because available software programmes cannot provide management option tables with annual F-factors which take account for weighted F.

Initial stock size: Input to the short-term projection are the stock number at age 4-15+ (survivors) at the 1st of January taken from the final assessment. For instance, if the last data year is 2008, the assessment provides the surviving stock numbers at the 1st of January 2009. Stock numbers at age 0-3 are estimated separately from independent data sources (for instance using RCT3).

Maturity: As a default a standard fixed maturity o-give is applied. In the case biological information is available indicating a change in proportions maturation at age, the values may be adjusted

age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	0	0	0	0	0.3	0.9	1	1	1	1	1	1	1	1	1	1

F and M before spawning: The SSB is calculated at the 1st of January. Consequently the proportion of F and M before spawning is 0.

Weight at age in the stock: for the intermediate year are the observed weights obtained from the winter survey (reference). For the other years the average of the last 3 years are used. Since 2008 the winter survey has stopped and weight at age data from commercial sampling in the same period and are used

Weight at age in the catch: is the average of the observed catch weights over the last three years.

Exploitation pattern: is the average over the last 3 years. In 2010 and 2011 the average over the last 5 years was used.

Natural mortality: fixed values, the same as used in the assessment

Intermediate year assumptions: catch constraint

Stock recruitment model used: not applicable

Procedures used for splitting projected catches: not applicable

E. Medium-Term Projections not defined

Model used:

Software used:

Initial stock size:

Natural mortality:

Maturity:

F and M before spawning:

Weight at age in the stock:

Weight at age in the catch:

Exploitation pattern:

Intermediate year assumptions:

Stock recruitment model used:

Uncertainty models used:

1. Initial stock size:
2. Natural mortality:
3. Maturity:
4. F and M before spawning:
5. Weight at age in the stock:
6. Weight at age in the catch:
7. Exploitation pattern:
8. Intermediate year assumptions:
9. Stock recruitment model used:

F. Long-Term Projections not defined

Model used:

Software used:

Maturity:

F and M before spawning:

Weight at age in the stock:

Weight at age in the catch:

Exploitation pattern:

Procedures used for splitting projected catches:

G. Biological Reference Points

G.1. Precautionary and limit reference points:

The reference points for herring were considered by the Workshop on Limit and Target Reference Points (WKREF) held in Gdynia in 2007. Although it was the intention to review and update the biological basis of limit reference point taking into account the possible effects of species interactions and regime shifts, this has not been done because of lack of data. Instead, the breakpoint of a segmented regression applied to the stock recruitment plot was investigated. This breakpoint gives an indication at which SSB recruitment starts to decline and is a candidate for Blim. The breakpoint in the stock recruit data varied between 2 to 4 million tonnes and seemed to be very sensitive to small changes in the estimates of the poor year classes (points near the origin of the S/R plot) in assessments carried out in different years. WKREF could not explain the sensitivity and considered this behaviour of the model highly undesirable. WKREF decided to ask the Methods Working Group to investigate this observation further. Given this, the use of segmented regression technique to establish a limit biomass reference point for Norwegian spring spawning herring was not considered appropriate until the observed methodological issue has been resolved.

The presently used values originate from an analysis carried out in 1998.

	ICES CONSIDERS THAT:	ICES PROPOSED THAT:
Precautionary Approach reference points	$\mathbf{B}_{lim}$ is 2.5 million t	$\mathbf{B}_{pa}$ be set at 5.0 million t
	$\mathbf{F}_{lim}$ is not considered relevant for this stock	$\mathbf{F}_{pa}$ be set at F = 0.15

Technical basis:	
$\mathbf{B}_{lim}$: MBAL	$\mathbf{B}_{pa}$=$\mathbf{B}_{lim}$*exp(0.4*1.645) (ICES Study Group 1998)
$\mathbf{F}_{lim}$: not relevant for this stock	$\mathbf{F}_{pa}$: based on medium term simulations (ICES Study Group 1998)

The new assessment did not give different perceptions of the dynamics and levels of SSB and Fishing Mortality compared to the assessment which was the basis for establishing the reference points. Therefore there was no need to reconsider the reference points because of the new assessment method.

MSY reference points (included in 2010)

HCS Simulation model analysis

HCS is a stochastic simulation model for studying different management scenarios. The parameterization of HCS for NSSH is described in a working document sent for WGWIDE in 2010 (WD, Skagen; the values for weights, natural mortality and initial N-values can be found in ICES 2009, WGWIDE Table 7.10.1.3, input to short term prediction; see also Skagen 2010, WD WKFRAME). Two stock-recruitment relationships, Beverton-Holt and hockey stick, are explored:

Beverton-Holt: $R = a*SSB/(SSB+b)$

Hockey stick: $S>b: R = a$

$S<b: R = a*SSB/b$

The stock-recruitment parameters are shown in Table 7.8.2. params, and a plot of these together with the data is shown in Figure 7.8.2.srstoch. A plot of the data together with model output for Beverton-Holt function is show in Figure 7.8.2 srmodeldata, and the cumulative distribution of recruitment in data and model output is shown in Figure 7.8.2.cumdist. The long term sustained yields with Beverton-Holt recruitment function are shown in Figure 7.8.2.catch. A similar figure for hockey stick recruitment function can be found in Skagen 2010 (WD, Skagen).

In WKHERMAT in 2010 a new maturity ogive matrix for NSSH based on a back calculation methods was estimated (ICES 2010, WKHERMAT). This is used in the assessment in 2010. There appears to be a difference in the maturation ogive between strong and weak year classes such that strong year classes tend to mature at later age compared to weak year classes (Engelhart & Heino 2004, ICES 2010, WKFRAME). However, the model used here currently allows only static maturity ogive, and in order to take into account the effect of variation in maturation of strong and weak year classes for MSY and F_{MSY} we have run the analysis using the standard maturity ogive used in assessment the latest years, an ogive estimated for weak year classes and an ogive estimated for strong year classes (Table 7.8.2.modelparams). Furthermore, in year 2009 the selection pattern is different to the historical period, appearing more dome-shaped than the historical sigmoidal selection pattern (Table 7.8.2.modelparams). We have not been able to identify any reason why the selection pattern would have changed, as there have been no changes in gear or fishery in general. Nevertheless, we also studied the effect of possible change in selection pattern by using alternatively the historical (old) or the selection curve from 2009 (Table 7.8.2.modelparams).

The results of the simulation analysis suggest that the MSY, for all the scenarios and with both stock-recruitment functions, is within the same range: between 1 and 1.2 million tonnes (Figure 7.8.2.msyBH, 7.8.2.msyHS, and Table 7.8.2.results). Even though the different scenarios result in MSY within the same range, the F_{MSY} has more variation (Figure 7.8.2.fmsy and Table 7.8.2.results). When Beverton-Holt recruitment function is used, the risk of stock going below B_{lim} (2.5 million t.) and $B_{trigger}$ (4 million t.) at F_{MSY} are both very low, whereas with the Hockey stick recruitment function the risk of the stock falling below $B_{trigger}$ at F_{MSY} is relatively high (Table 7.8.2.results). Hockey stick recruitment function appears not to be very useful in modelling population dynamics, as the spawning stock size where MSY is reached is the same point where stock reproductive capacity starts decreasing (see also the discussion in the equilibrium analysis below). When Beverton-Holt recruitment function is used, unweighted F_{MSY} using the historical fishery selection pattern is 0.16 (for all maturity ogive scenarios), and adopting the 2009 selection pattern suggests of F_{MSY} 0.12 (for all maturity ogive scenarios). In NSSH management weighted F values are used, and the weighted values tend to be somewhat lower than unweighted values (Figure 7.8.2.fvalues). As we have no reason to believe that the selection pattern has really changed, we consider unweighted F_{MSY} to be 0.16. This unweighted F value is in close agreement with the reference values originating from an analysis carried out in 1998 (ICES 2008/ACOM 13), where a weighted F_{pa} is defined as 0.150.

<u>Equilibrium and YPR analyses</u>

Deterministic and stochastic equilibrium analyses were carried out using the 'plotMSY' software (ICES 2010, WKFRAME) to determine candidate F_{MSY} values for the Norwegian spring spawning herring stock. Stock-recruitment pairs from the period 1988-2009, as outputted from the most recent assessment of the stock, were used together with 5-year averages of selectivity, weight and maturity at age (back-calculated ogive). Two stock recruit relationships were examined, Beverton and Holt and the ('smooth hockey stick' (segmented regression), and yield-per-recruit (YPR) analyses were also done. For the stochastic analyses, uncertainty (CVs) in the biological and fishery parameters at age were used to create alternative fits to two stock-recruit relationships (*N*=1000).

While the Beverton and Holt fit is reasonable under using the old maturity ogive to estimate SSB (results not shown), the majority of stochastic stock-recruit model fits fell out of the range of the deterministic fit to the data, and thus it can be concluded that the stock-recruit form is unclear and not suitable for the data and the level of uncertainty associated with the parameters. Using the new back-calculated maturity ogive, as has been decided by the working group for the assessment of this stock, results in an very poor Beverton and Holt fit (Figure 7.8.2.XXXsr), with an extremely steep slope at the origin and an asymptote at the geometric mean recruitment level. Given the lack of any clear patterns in the stock-recruit data, a hockey stick model fit, while uncertain around the origin, probably provides the most cautious fit to the data. For the hockey stick, the slope at the origin is the descending limb of the stock-recruit curve, which for this stock is relatively shallow, hence F_{crash} is low. The value for B_{msy} is at the breakpoint in the hockey stick, hence F_{msy} is estimated to be the same as F_{crash} (Table 7.8.2.XXXmsy). The uncertainty with regards to the slope at the origin makes this stock-recruitment function unsuitable as a basis for advice on F_{msy}. In such cases the slope is more useful as an indication of F_{pa} or F_{lim}.

Given the poor fits to stock recruitment functions, a yield-per-recruit analysis was conducted (Figure 7.8.2.XXXypr). The stochastic analysis shows a high degree of uncertainty and a very poorly defined F_{max}. That both the hockey stick and per-recruit analysis suggests a high degree of uncertainty with regards to F_{max} could be down to the assumptions made about the uncertainties input into the analyses, though these assumptions are believed to be realistic given the information on the stock. This would preclude the use of F_{max} as an F_{msy} proxy, although $F_{0.1}$ may remain a viable, safer alternative. The YPR curve shows that F values in the range 0.125-0.15 are likely to result in high long term yields.

Conclusions

In the equilibrium analysis, the structure of the stock and recruitment pairs as estimated from the most recent assessment does not lead to any clear definition of an optimum yield equilibrium fishing mortality level. Given this uncertainty it is more appropriate to select an F_{msy} proxy tested by a stochastic simulation model that takes into account the long term trends in the stock biomass. The simulation model results presented in this report and in the stock annex provide a more appropriate method for the determining a viable long term target, and the values from this analysis could be put forward as potential F_{msy} targets. However, it should be noted that it is clear that the estimation of MSY reference points is very sensitive to the choice of stock-recruitment function and the approach chosen to estimate the reference points. This is in accordance with previous analyses by Skagen (WD 2010) and by WKFRAME (ICES 2010, WKFRAME).

The stochastic model uses unweighted F values, which have historically been found to be slightly lower than the unweighted values (Figure 7.8.2.fvalues). Therefore, a weighted F_{msy} of 0.15 corresponding to the unweighted 0.16 F_{msy} proxy from the simulation analyses is proposed for this stock. This is in agreement with the current simulation-tested management plan F_{pa} level and should ensure high long term yield with a low risk to the stock.

Table 7.8.2.params. Norwegian spring spawning herring. Stock recruitment parameters used in the simulation model and their fit to the data (Skagen 2010).

	a-parameter	b-parameter	SSQ
Beverton-Holt	180805	6986	81.85
Hockey stick	88803	3957	81.47

Table 7.8.2.modelparams. Norwegian spring spawning herring. Age-specific maturation probabilities, exploitation patterns and weight at age in stock and in catches used in the different stochastic simulation scenarios.

	Maturity ogive			Exploitation pattern		Weight at age	
Age	historic	weak year class	Strong year class	Old	2009	stock	catch
0	0	0	0	0.00	0.00	0.001	0
1	0	0	0	0.05	0.00	0.01	0.052
2	0	0	0	0.04	0.87	0.033	0.115
3	0	0	0	0.05	0.26	0.077	0.159
4	0.3	0.4	0.1	0.18	0.29	0.141	0.225
5	0.9	0.8	0.6	0.41	0.47	0.215	0.264
6	1	1	0.9	0.67	0.84	0.27	0.301
7	1	1	1	1.03	0.93	0.306	0.32
8	1	1	1	1.10	1.01	0.336	0.338
9	1	1	1	0.81	1.65	0.346	0.359
10	1	1	1	1.03	1.10	0.364	0.366
11	1	1	1	0.77	0.73	0.369	0.375
12	1	1	1	1.42	1.14	0.411	0.391
13	1	1	1	1.36	0.59	0.353	0.397
14	1	1	1	1.39	0.56	0.389	0.396
15	1	1	1	1.39	0.56	0.393	0.406

Table 7.8.2.results. Norwegian spring spawning herring. MSY and FMSY values provided by HCS model for different scenario combinations. Risk B_{lim} refers to the probability that SSB < B_{lim} in the last year (2.5 million tonnes), and Risk $B_{trigger}$ refers to the probability that SSB < $B_{trigger}$ ($B_{trigger}$ = 5 million tonnes, risk calculated as risk B_{lim}).

		Beverton-Holt				Hockey stick			
Ogive	selection pattern	F_{MSY}	MSY	Risk Blim	Risk Btrigger	F_{MSY}	MSY	Risk Blim	Risk Btrigger
Historical	old	0.16	1120.1	0	0.026	0.32	1180.1	0.067	0.354
	2009	0.12	1071.5	0.006	0.064	0.2	1135.7	0.088	0.431
Weak year class	old	0.16	1132.8	0	0.022	0.32	1193.4	0.058	0.321
	2009	0.12	1083.4	0.006	0.051	0.2	1149.4	0.075	0.401
Strong year class	old	0.16	1093.3	0.002	0.045	0.26	1157.9	0.04	0.232
	2009	0.12	1046.4	0.007	0.086	0.16	1117.9	0.017	0.203

Table 7.8.2.msy. Deterministic and stochastic estimates of *F* and biomass reference points form two stock recruit relationships and yield-per-recruit analysis for the Norwegian spring spawning herring stock (*=poorly defined).

Beverton-Holt

	Fcrash	Fmsy	Bmsy	MSY
Deterministic	*	*	0.25	1.06
50%ile	0.52	0.15	3.11	0.61
CV	1.09	0.60	0.72	0.61

Hockey Stick

	Fcrash	Fmsy	Bmsy	MSY
Deterministic	0.18	0.18	4.25	0.70
50%ile	0.20	0.20	3.88	0.90
CV	0.71	0.69	0.39	0.49

Per recruit

	F01	Fmax
Deterministic	0.23	*
50%ile	0.19	0.77
CV	0.39	0.58

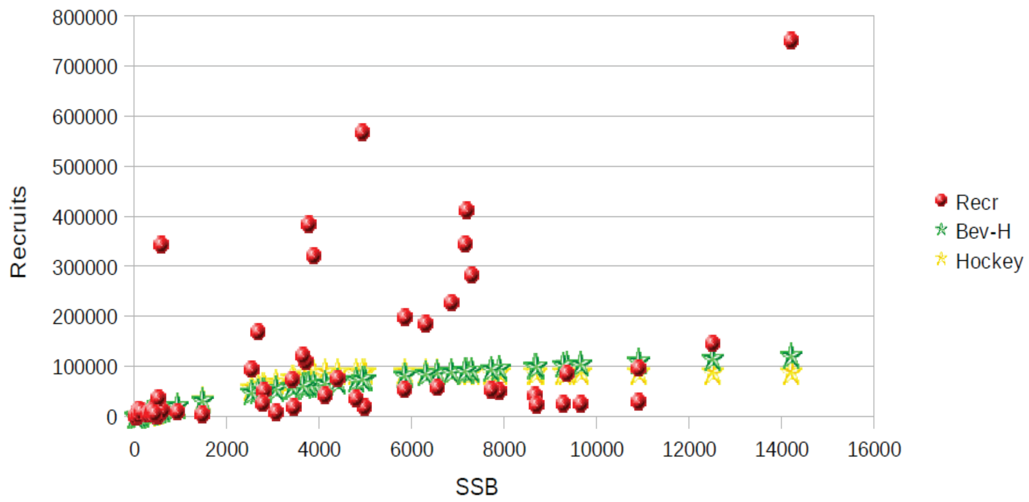


Figure 7.8.2. srstoch. Stock recruitment relationship used in the simulation model. Red dots show the recruitment from data, green stars the fitted Beverton-Holt function and yellow stars the fitted hockey stick function. Figure show also in Skagen 2010 (WD, Skagen).

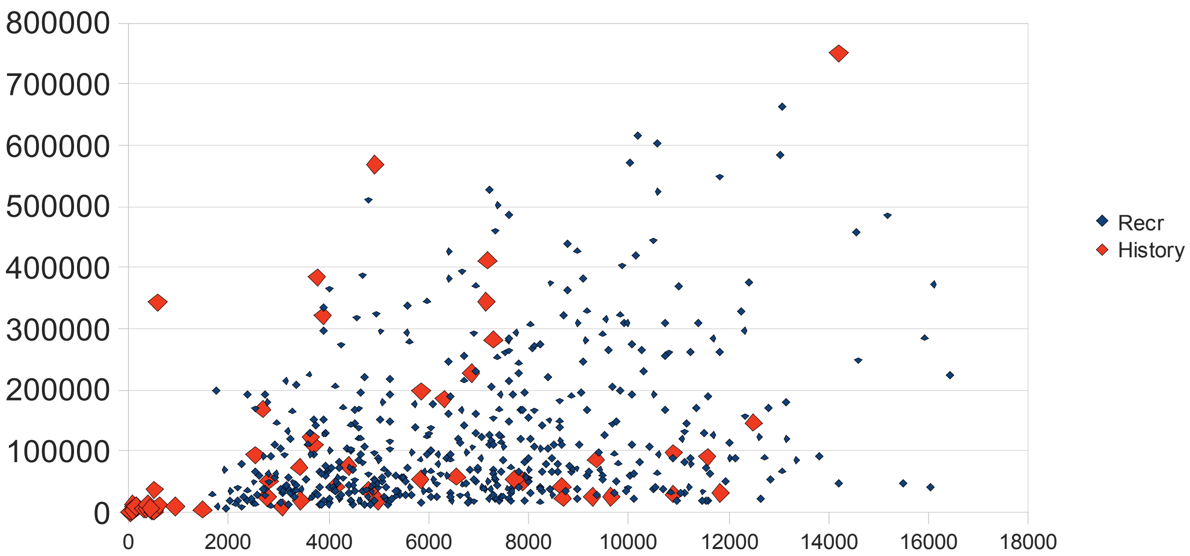


Figure 7.8.2.srmodeldata. Norwegian spring spawning herring. Stock-recruitment of NSSH from data (big red diamonds) and produced by the model (blue small diamonds) using Beverton-Holt recruitment function.

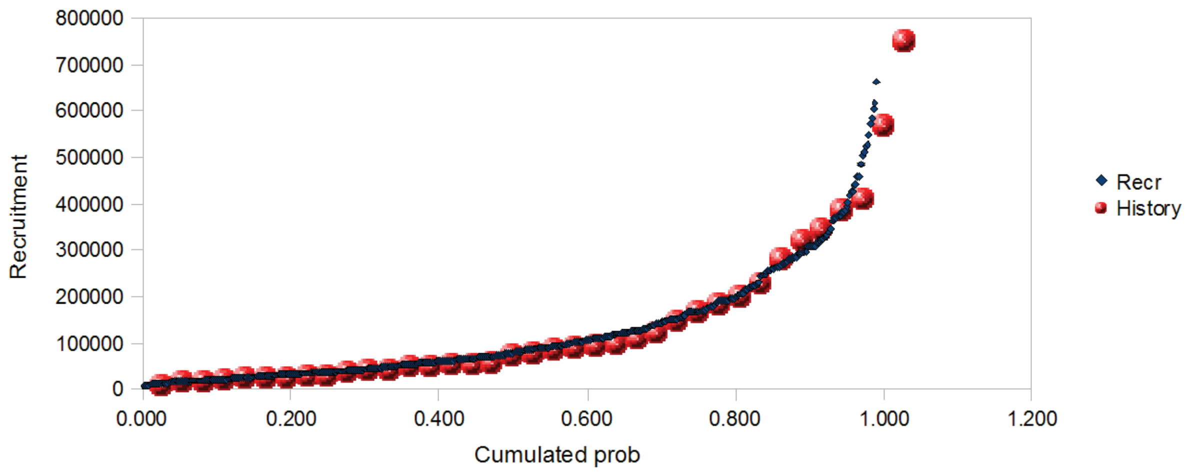


Figure 7.8.2.cumdist. Norwegian spring spawning herring. Cumulative probability of recruitment values of NSSH from the data (red dots) and produced by the model (small blue diamonds) using Beverton-Holt recruitment function.

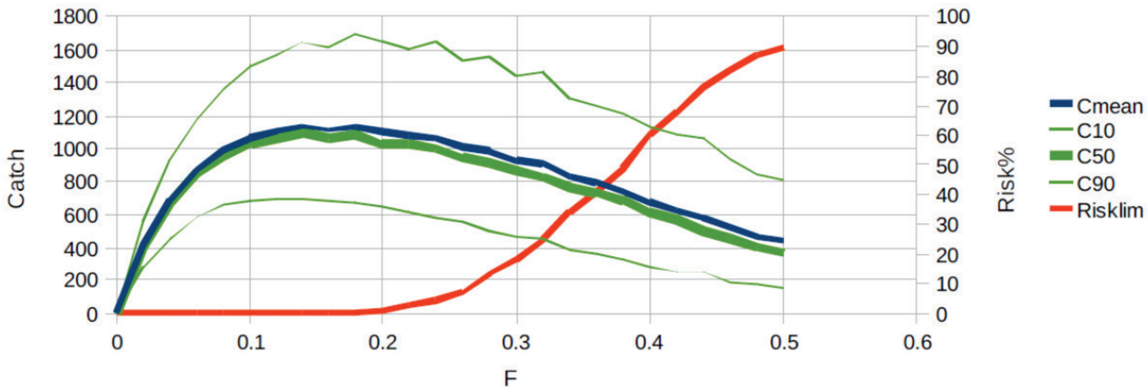


Figure 7.8.2.catch. Norwegian spring spawning herring. Yield (catch) and the probability of the stock being below Blim (2.5. million tonnes) after 50 years at target F for NSSH using Beverton-Holt recruitment function. C10, C50 and C90 show the 10, 50 and 90 percentiles of catch. Risklim shows the probability of stock falling below B_{lim} as a percentage of the model runs. For similar figure for hockey stick recruitment function see WD Skagen 2010.

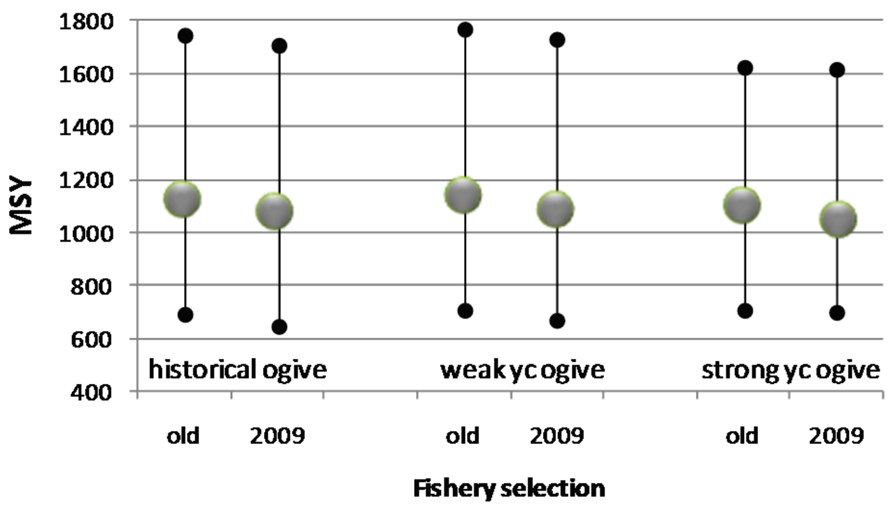


Figure 7.8.2.msyBH. Norwegian spring spawning herring. The MSY for three different maturity ogives and two different fishery selection patterns with 10 and 90 percentiles using Beverton-Holt recruitment function. See text for further details.

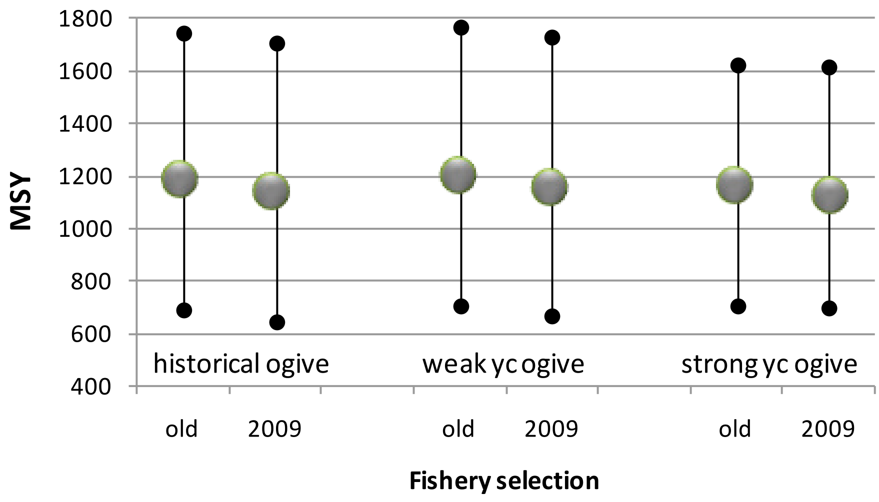


Figure 7.8.2.msyHS. Norwegian spring spawning herring. The MSY for three different maturity ogives and two different fishery selection patterns with 10 and 90 percentiles using hockey stick recruitment function. See text for further details.

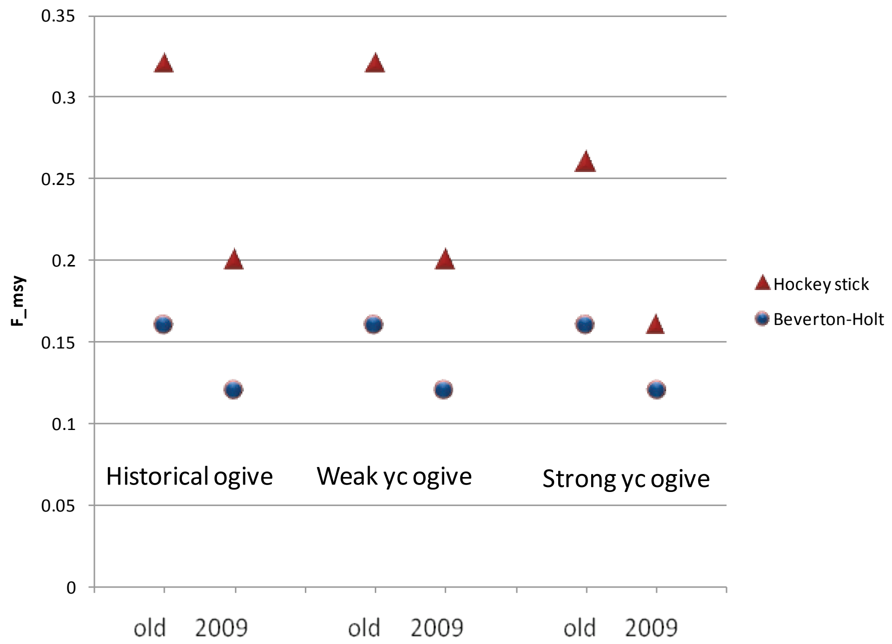


Figure 7.8.2.fmsy. Norwegian spring spawning herring. F_{MSY} for three different maturity ogives and two different fishery selection patterns with Beverton-Holt and hockey stick recruitment function. See text for further details.

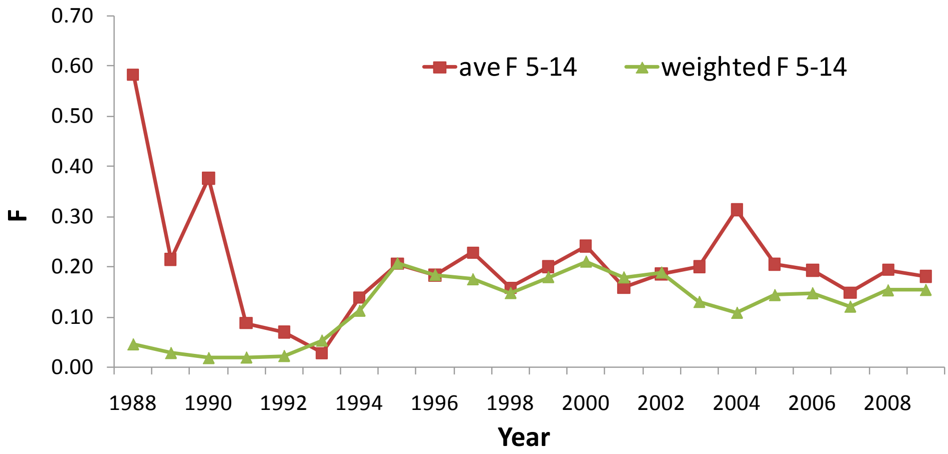


Figure 7.8.2.fvalues. Norwegian spring spawning herring. Unweighted (red squares) and weighted (green triangles) average F values from the current assessment.

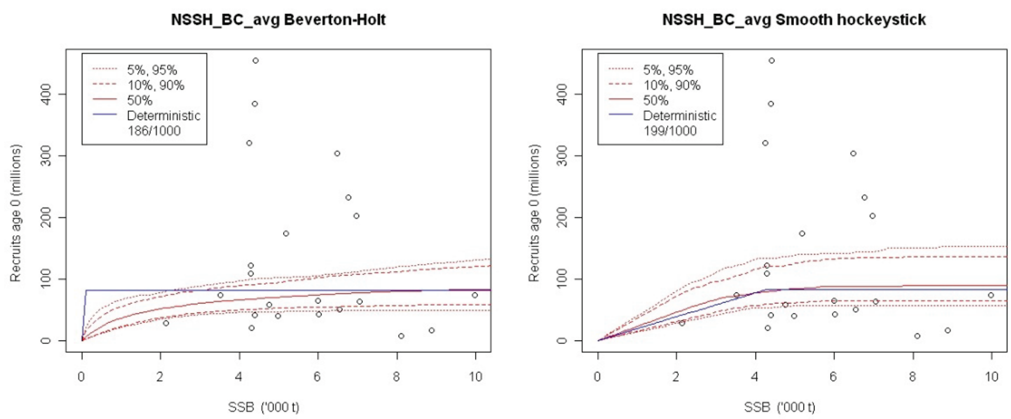


Figure 7.8.2.sr. Deterministic and stochastic (taking into account uncertainty in weights, selectivity and maturity at age) stock recruit relationship fits for the Norwegian spring spawning herring stock. Stock-recruit pairs are from the period 1988-2009.

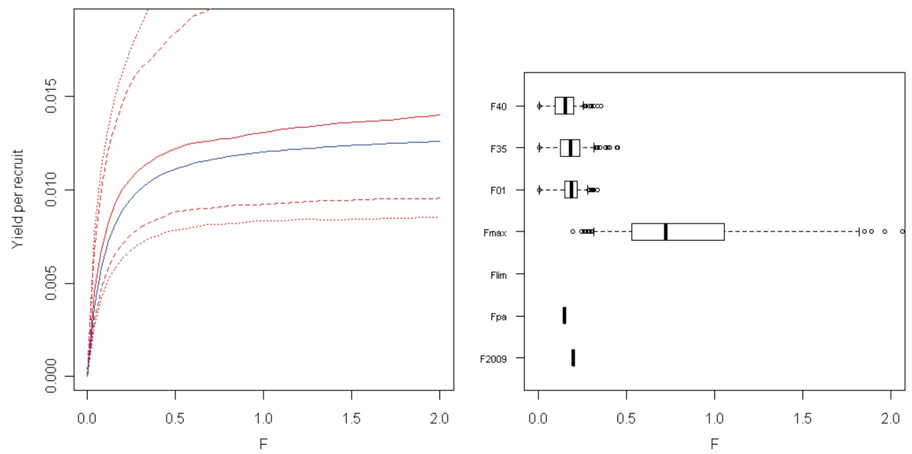


Figure 7.8.2 ypr. The yield-per-recruit (YPR) curve for the Norwegian spring spawning herring stock (left) and resulting stochastic estimates of *F* reference points (right).

G.3. Target reference points

The Coastal States have agreed a target reference point defined at F=0.125. (Note that the average fishing mortality is calculated as a weighted mean over the age groups 5–14 (weighted over abundance).

H. Other Issues not defined

Table B.2.4.1. Norwegian spring spawning herring. Maturity at age information used in the assessments before the 2010 assessments.

	age																
Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1950	0	0	0	0	0.1	0.3	0.6	0.9	1	1	1	1	1	1	1	1	1
1951	0	0	0	0	0.1	0.3	0.6	0.9	1	1	1	1	1	1	1	1	1
1952	0	0	0	0	0.1	0.3	0.6	0.9	1	1	1	1	1	1	1	1	1
1953	0	0	0	0	0.1	0.3	0.6	0.9	1	1	1	1	1	1	1	1	1
1954	0	0	0	0	0.1	0.3	0.6	0.9	1	1	1	1	1	1	1	1	1
1955	0	0	0	0.08	0.22	0.37	0.85	1	1	1	1	1	1	1	1	1	1
1956	0	0	0	0.08	0.22	0.37	0.85	1	1	1	1	1	1	1	1	1	1
1957	0	0	0	0	0	0.5	0.6	1	1	1	1	1	1	1	1	1	1
1958	0	0	0	0.08	0.22	0.37	0.85	1	1	1	1	1	1	1	1	1	1
1959	0	0	0	0.08	0.22	0.37	0.85	1	1	1	1	1	1	1	1	1	1
1960	0	0	0	0.08	0.22	0.37	0.85	1	1	1	1	1	1	1	1	1	1
1961	0	0	0	0.04	0.35	0.68	0.94	1	1	1	1	1	1	1	1	1	1
1962	0	0	0	0	0.11	0.67	1	1	1	1	1	1	1	1	1	1	1
1963	0	0	0	0.04	0.03	0.32	0.9	1	1	1	1	1	1	1	1	1	1
1964	0	0	0	0.02	0.06	0.28	0.32	1	1	1	1	1	1	1	1	1	1
1965	0	0	0	0	0.34	0.35	0.76	1	1	1	1	1	1	1	1	1	1
1966	0	0	0	0.01	0.15	1	0.96	1	1	1	1	1	1	1	1	1	1
1967	0	0	0	0	0.01	0.23	1	1	1	1	1	1	1	1	1	1	1
1968	0	0	0	0	0	0.01	0.76	1	1	1	1	1	1	1	1	1	1
1969	0	0	0	0.62	0.89	0.95	1	1	1	1	1	1	1	1	1	1	1
1970	0	0	0	0.06	0.13	0.31	0.17	1	1	1	1	1	1	1	1	1	1
1971	0	0	0	0.1	0.25	0.6	0.9	1	1	1	1	1	1	1	1	1	1
1972	0	0	0	0	0.1	0.25	0.6	0.9	1	1	1	1	1	1	1	1	1
1973	0	0	0	0.5	0.9	1	1	1	1	1	1	1	1	1	1	1	1
1974	0	0	0	0.5	0.9	1	1	1	1	1	1	1	1	1	1	1	1
1975	0	0	0	0.5	1	1	1	1	1	1	1	1	1	1	1	1	1
1976	0	0	0	0.5	0.9	1	1	1	1	1	1	1	1	1	1	1	1
1977	0	0	0	0.73	0.89	1	1	1	1	1	1	1	1	1	1	1	1
1978	0	0	0	0.13	0.9	1	1	1	1	1	1	1	1	1	1	1	1
1979	0	0	0	0.1	0.62	0.95	1	1	1	1	1	1	1	1	1	1	1
1980	0	0	0	0.25	0.5	0.97	1	1	1	1	1	1	1	1	1	1	1
1981	0	0	0	0.3	0.5	0.9	1	1	1	1	1	1	1	1	1	1	1
1982	0	0	0	0.1	0.48	0.7	1	1	1	1	1	1	1	1	1	1	1
1983	0	0	0	0.1	0.5	0.69	0.71	1	1	1	1	1	1	1	1	1	1
1984	0	0	0	0.1	0.5	0.9	0.95	1	1	1	1	1	1	1	1	1	1
1985	0	0	0	0.1	0.5	0.9	1	1	1	1	1	1	1	1	1	1	1
1986	0	0	0	0.1	0.2	0.9	1	1	1	1	1	1	1	1	1	1	1

Table B.2.4.1, cont. Norwegian spring spawning herring. Maturity at age information used in the assessments before the 2010 assessments.

	age															
Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1987	*0*	*0*	*0*	*0.1*	*0.3*	*0.9*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
1988	*0*	*0*	*0*	*0.1*	*0.3*	*0.9*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
1989	*0*	*0*	*0*	*0.1*	*0.3*	*0.9*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
1990	*0*	*0*	*0*	*0.4*	*0.8*	*0.9*	*0.9*	*0.9*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
1991	*0*	*0*	*0*	*0.1*	*0.7*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
1992	*0*	*0*	*0*	*0.1*	*0.2*	*0.8*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
1993	*0*	*0*	*0*	*0.01*	*0.3*	*0.8*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
1994	*0*	*0*	*0*	*0.01*	*0.3*	*0.8*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
1995	*0*	*0*	*0*	*0*	*0.3*	*0.8*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
1996	*0*	*0*	*0*	*0*	*0.3*	*0.9*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
1997	*0*	*0*	*0*	*0*	*0.3*	*0.9*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
1998	*0*	*0*	*0*	*0*	*0.3*	*0.9*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
1999	*0*	*0*	*0*	*0*	*0.3*	*0.9*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
2000	*0*	*0*	*0*	*0*	*0.3*	*0.9*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
2001	*0*	*0*	*0*	*0*	*0.3*	*0.9*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
2002	*0*	*0*	*0*	*0*	*0.3*	*0.9*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
2003	*0*	*0*	*0*	*0*	*0.3*	*0.9*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
2004	*0*	*0*	*0*	*0*	*0.3*	*0.9*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
2005	*0*	*0*	*0*	*0.1*	*0.3*	*0.9*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
2006	*0*	*0*	*0*	*0*	*0.9*	*0.9*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
2007	*0*	*0*	*0*	*0*	*0.3*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*

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Table B.3.1.1. Norwegian Spring-spawning herring. Estimates from the acoustic surveys on the spawning stock in February-March. Numbers in millions. Biomass in thousands. Data in black box are used in assessment. There have been corrections due to age readings. ***Survey 1.***

	SURVEY 1							age							Total
Year	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Total	Biomass
1988		255	146	6805	202										7408	
1989	101	5	373	103	5402	182									6166	
1990	183	187	0	345	112	4489	146								5462	
1991	44	59	54	12	354	122	4148	102							4895	
1992*																
1993*																
1994	16	128	676	1375	476	63	13	140	35	1820					4742	
1995		1792	7621	3807	2151	322	20	1	124	63	2573				18474	3514
1996	407	231	7638	11243	2586	957	471	0	0	165	0	2024			25722	4824
1997*																
1998			381	1905	10640	6708	1280	434	130	39	0	64	0	915	22496	5360
1999	106	1366	337	1286	2979	11791	7534	1912	568	132	0	0	392	437	28840	7213
2000	1516	690	1996	164	592	1997	7714	4240	553	71	3	0	6	24	19566	4913
2001**																
2002**																
2003**																
2004**																
2005	103	281	811	3310	7545	10453	887	563	159	122	610	1100	686		26649	6501
2006	13	75	10167	684	1103	4540	4407	133	47	11	113	120	323	135	21871	4858
2007	109	534	2097	14575	952	592	3270	3092	263	276	20	285	189	628	26882	6004
2008	10	145	3517	3749	15066	972	612	2410	2374	426	136	121	90	171	29798	7244

*** No estimate due to poor weather conditions.**

**** No surveys.**

Table B.3.2.1 Norwegian Spring-spawning herring. Estimates obtained on the acoustic surveys in the wintering areas in November-December. Numbers in millions. Data in black box are used in assessment. There have been corrections due to age readings. *Survey 2*.

	SURVEY 2					age									Total
year	1	2	3	4	5	6	7	8	9	10	11	12	13	14+	total	biomass
1992		36	1247	1317	173	16	208	139	3742	69					6947	
1993	72	1518	2389	3287	1267	13	13	158	26	4435					13178	
1994		16	3708	4124	2593	1096	34	25	196	29	3239				15209	
1995	380	183	5133	5274	1839	1040	308	19	13	111	39	907			15246	
1996		1465	3008	13180	5637	994	552	92	0	7	41	15	393		25384	
1997	9	73	661	1480	6110	4458	1843	743	66	0	0	64	0	904	16411	
1998	65	1207	441	1833	3869	12052	8242	2068	629	111	14	0	40	573	31144	
1999	74	159	2425	296	837	2066	6601	4168	755	212	0	15	0	146	17754	
2000	56	322	1522	5260	165	497	1869	4785	3635	668	205	0	0	11	18995	
2001	362	522	3916	1528	2615	82	338	864	3160	2216	384	127	0	1	16115	
2002*	7	50	276	1659	624	1029	32	188	516	1831	911	184	0	0	7307	
2003**	586	406	2167	10670	13237	1047	678	41	134	301	1214	502	10	37	31030	
2004**	257	6814	1123	1596	5334	6731	363	280	37	42	187	761	392	83	24000	
2005	61	352	7173	465	685	2030	3101	177	190	57	46	184	476	327	15325	
2006	940	7785	3712	21320	1153	340	2879	4851	4	23	713	4	150	58	43778	
2007	1233	343	4161	2407	6213	226	288	695	694	0	43	0	126	188	16617	3660

*** Much of the youngest yearclasses (-98,-99) wintered outside the fjords this winter and are not included in the estimate**

**** In 2003-2004 a combined estimate from the Tysfjord, Ofotfjord and oceanic areas off Vesterålen/Troms.**

Table B.3.3.1 Norwegian spring spawning herring. Estimates obtained on the acoustic surveys in the wintering areas in January. Numbers in millions. Data in the black box are used in the assessment. There have been corrections due to age readings. ***Survey 3.***

	SURVEY 3						age							
Year	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Total
1991	90	220	70	20	180	150	5500	440							6670
1992		410	820	260	60	510	120	4690	30						6900
1993		61	1905	2048	256	27	269	182	5691	128					10567
1994	73	642	3431	4847	1503	102	29	161	131	3679					14598
1995		47	3781	4013	2445	1215	42	24	267	29	4326				16189
1996		315	10442	13557	4312	1271	290	22	25	200	58	1146			31638
1997*															-
1998	214	267	1938	4162	9647	6974	1518	743	16	4	0	33	7	462	25985
1999**	0	1358	199	1455	4452	12971	7226	1876	499	16	16	0	156	220	30444

*** No estimate due to poor weather conditions.**

**** No surveys since 1999.**

Table B.3.4.1. Norwegian spring-spawning herring. Acoustic estimates (billion individuals) of immature herring in the Barents Sea in May/June. No survey in 2003, 1990-2002. See footnotes. Data in black box used in the assessment except the yellow highlighted cell. ***Survey 4.***

	survey 4		age		
Year	1	2	3	4	5
1991	24.3	5.2			
1992	32.6	14	5.7		
1993	102.7	25.8	1.5		
1994	6.6	59.2	18	1.7	
1995	0.5	7.7	8	1.1	
1996[1]	0.1	0.25	1.8	0.6	0.03
1997[2]	2.6	0.04	0.4	0.35	0.05
1998	9.5	4.7	0.01	0.01	0
1999	49.5	4.9	0	0	0
2000	105.4	27.9	0	0	0
2001	0.3	7.6	8.8	0	0
2002	0.5	3.9	0	0	0
2003[3]					
2004[3]					
2005	23.3	4.5	2.5	0.4	0.3
2006	3.7	35.0	5.3	0.87	0
2007	2.1	3.7	12.5	1.9	0
2008[4]	0.043	0.38	0.2	0.28	0
2009	0.191	0.845	2.180	2.643	1.213

[1] Average of Norwegian and Russian estimates

[2] Combination of Norwegian and Russian estimates as described in 1998 WG report, since then only Russian estimates

[3] No surveys

[4] Not a full survey

Table B.3.4.2. Norwegian spring spawning herring. Estimates from the international acoustic surveys on the feeding areas in the Norwegian Sea in May. Numbers in millions. Biomass in thousands. Data in black box are used in assessment. There have been corrections due to age readings. ***Survey 5.***

	survey 5							Age									Total
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Total	Biomass
1996	0	0	4114	22461	13244	4916	2045	424	14	7	155	0	3134			50514	8532
1997	0	0	1169	3599	18867	13546	2473	1771	178	77	288	190	60	2697		44915	9435
1998	24	1404	367	1099	4410	16378	10160	2059	804	183	0	0	35	0	492	37415	8004
1999	0	215	2191	322	965	3067	11763	6077	853	258	5	14	0	158	128	26016	6299
2000	0	157	1353	2783	92	384	1302	7194	5344	1689	271	0	114	0	75	20758	6001
2001	0	1540	8312	1430	1463	179	204	3215	5433	1220	94	178	0	0	6	23274	3937
2002	0	677	6343	9619	1418	779	375	847	1941	2500	1423	61	78	28	0	26089	4628
2003	32073	8115	6561	9985	9961	1499	732	146	228	1865	2359	1769		287	0	75580	6653
2004	0	13735	1543	5227	12571	10710	1075	580	76	313	362	1294	1120	10	88	48704	7687
2005	0	1293	19679	1353	1765	6205	5371	651	388	139	262	526	1003	364	115	39114	5109
2006	0	19	306	14560	1396	2011	6521	6978	679	713	173	407	921	618	243	35545	9100
2007	0	411	2889	5877	20292	1260	1992	6780	5582	647	488	372	403	1048	1010	49051	12161
2008	0	1193	587	8332	8270	16345	1381	1920	3958	2500	416	242	159	217	408	45928	9996
2009	202	906	2980	2754	14292	9487	11629	1472	1253	2587	1357	267	183	60	258	49687	10700

Table B.3.5.1. Norwegian spring-spawning herring. Abundance indices for 0-group herring 1980-2008 in the Barents Sea, August-October. *This index has been recalculated since 2006, these are the new values. Survey 7.*

survey 7	
Year	Abundance index
1980	4
1981	3
1982	202
1983	40557
1984	6313
1985	7237
1986	7
1987	2
1988	8686
1989	4196
1990	9508
1991	81175
1992	37183
1993	61508
1994	14884
1995	1308
1996	57169
1997	45808
1998	79492
1999	15931
2000	49614
2001	844
2002	23354
2003	28579
2004	133350
2005	26332
2006	66819
2007	22481
2008	15727

Table B.3.5.2. Norwegian spring-spawning herring. Acoustic estimates (billion individuals) of immature herring in the Barents Sea in August-October. Data in black boxes used in the assessment. *Survey 6.*

survey 6			
	Age		
Year	1	2	3
2000	14.7	11.5	0
2001	0.5	10.5	1.7
2002	1.3	0	0
2003	99.9	4.3	2.5
2004	14.3	36.5	0.9
2005	46.4	16.1	7.0
2006	1.6	5.5	1.3
2007	3.9	2.6	6.3
2008	0.03	1.6	4.0

Table B.3.6.1.. Norwegian Spring-spawning herring. The indices for herring larvae on the Norwegian shelf for the period 1981-2009 (N*10^{-12}). Data in black box are used in the assessment. ***Survey 8.***

survey 8		
Year	Index1	Index 2
1981	0.3	
1982	0.7	
1983	2.5	
1984	1.4	
1985	2.3	
1986	1	
1987	1.3	4
1988	9.2	25.5
1989	13.4	28.7
1990	18.3	29.2
1991	8.6	23.5
1992	6.3	27.8
1993	24.7	78
1994	19.5	48.6
1995	18.2	36.3
1996	27.7	81.7
1997	66.6	147.5
1998	42.4	138.6
1999	19.9	73
2000	19.8	89.4
2001	40.7	135.9
2002	27.1	138.6
2003*	3.7	18.8
2004	56.4	215.1
2005	73.91	196.7
2006	98.9	389.0
2007**	90.6	
2008	107.9	393.3
2009***	8.4	53.8

Index 1. The total number of herring larvae found during the cruise.

Index 2. Back-calculated number of newly hatched larvae with 10% daily mortality. The larval age is estimated from the duration of the yolksac stages and the size of the larvae.

*** Poor weather conditions and survey was late in April**

**** only representative for the area 62-66°N**

*****Likely that spawning was particularly early in 2009**

Table B.3.7.1. Norwegian spring spawning herring. Acoustic estimates from the coordinated ecosystem survey in Norwegian Sea and adjoining waters in July-August. Numbers in millions. Biomass in thousands. ***Survey 9.***

	survey 9						Age									Total
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Total	Biomass
2009	0	415	4136	3522	12448	7479	12362	1223	2144	1761	410	0	157	75	756	46888	13603
2010	543	327	1309	2631	2500	10141	6619	6471	1163	2310	804	422	166	87	144	35637	10717

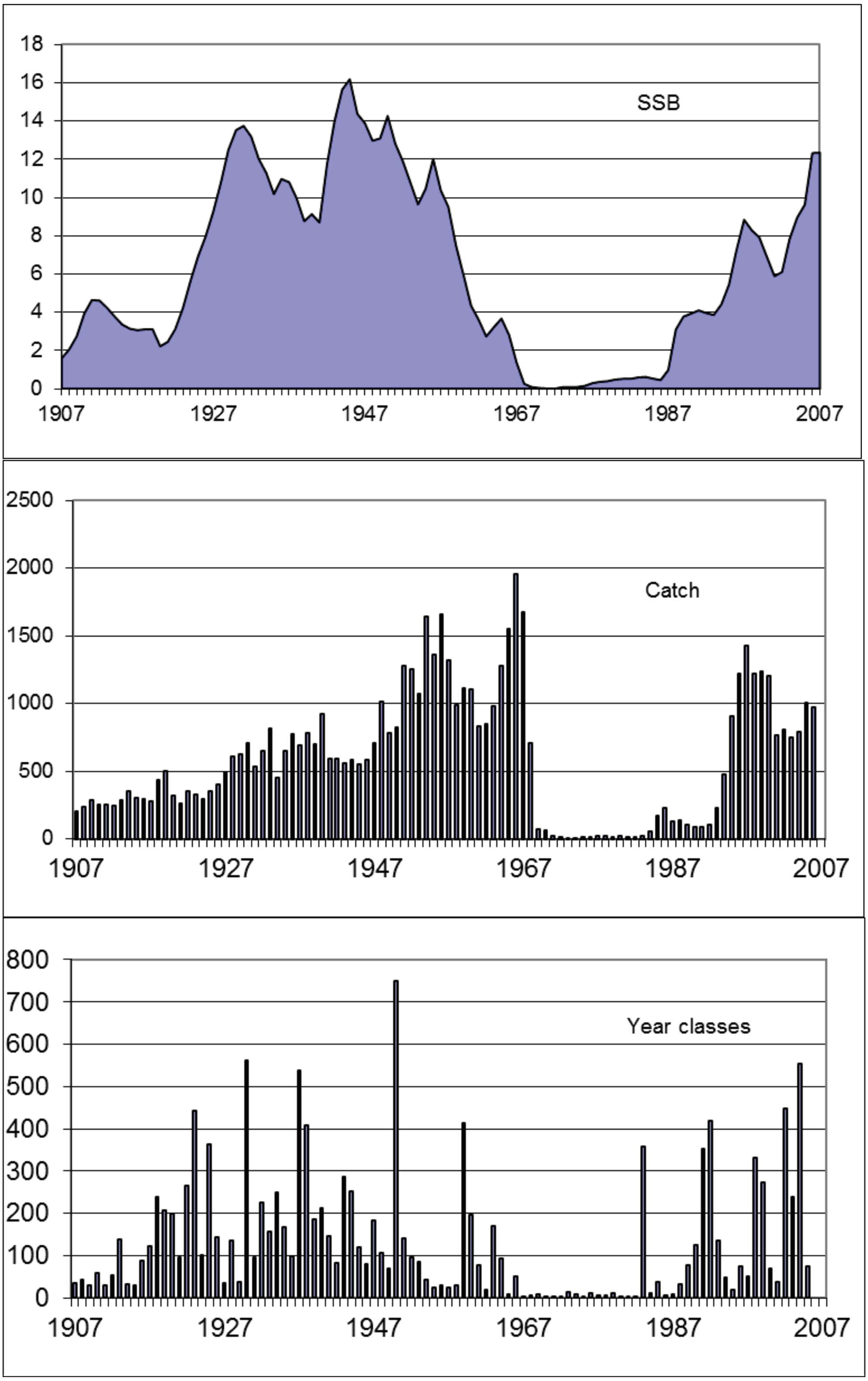

Figure A.1.1.1. Norwegian spring spawning herring. Long term trends in spawning stock, catches and recruits (1907-1988 from Toresen and Østvedt; 1989-2007 from WGNPBW 2007).

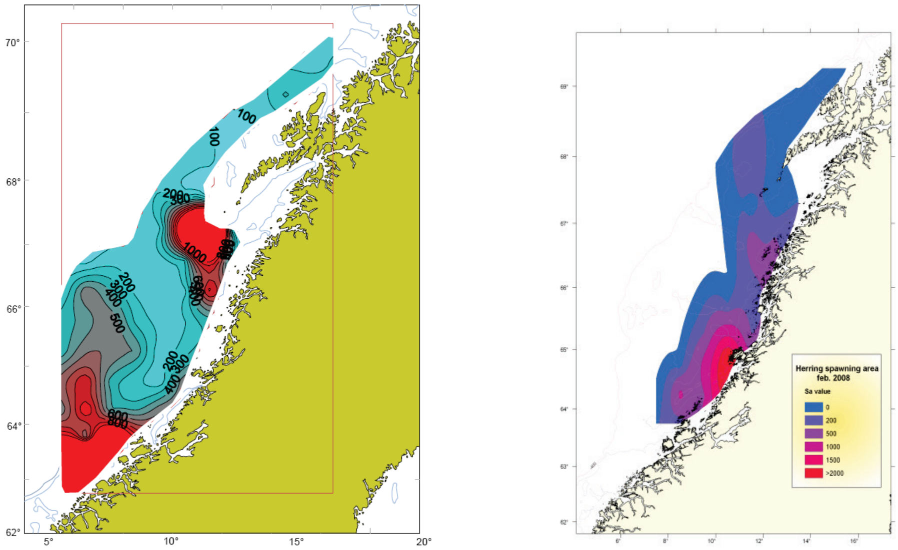

Figure B.3.1.1. NSSH Acoustic survey on spawning grounds in February March, 2007 (left) and 2008 (right).

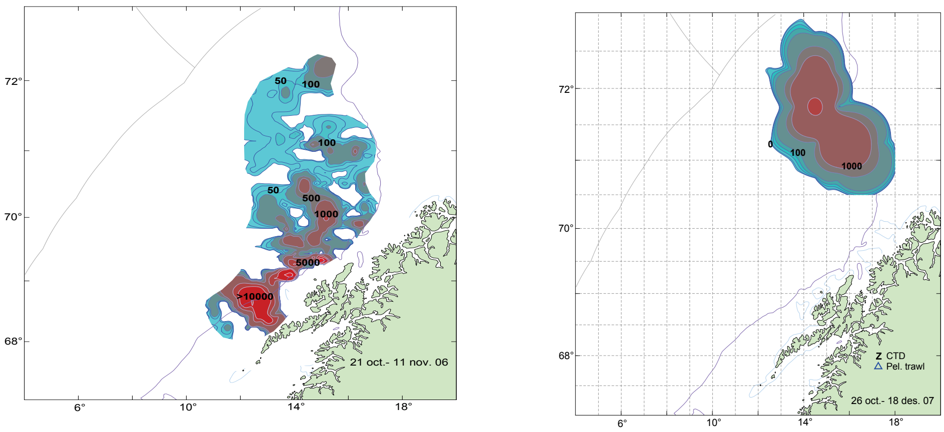

Figure B.3.2.1. NSSH Acoustic survey in November/December 2006 (left panel here) and 2007 (right panel).

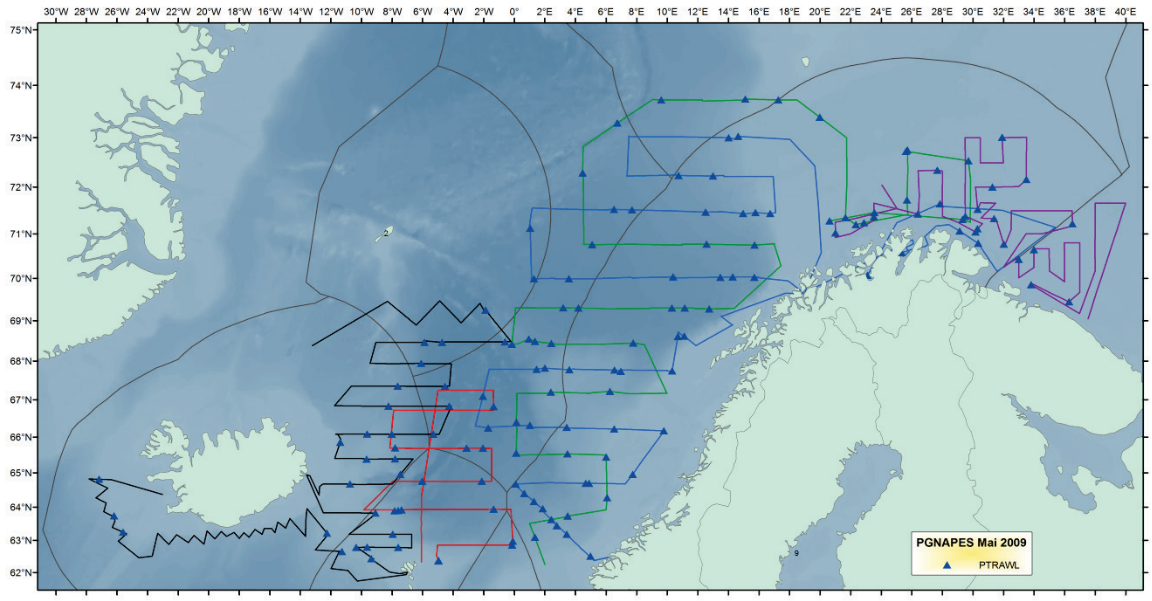

Figure B.3.4.1. Cruise tracks during the International North East Atlantic Ecosystem Survey in April-May 2009 and location of trawl stations.

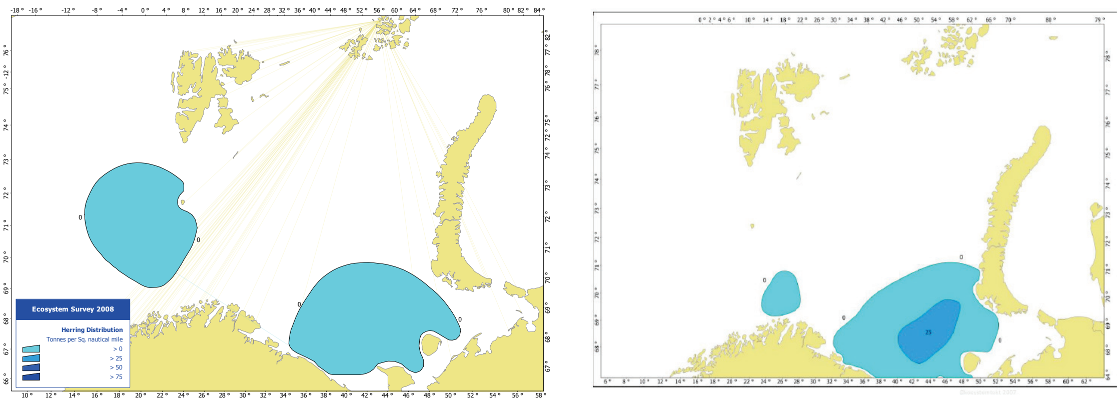

Figure B.3.5.1. Estimated total density of herring (tonnes/nautical mile²) in August-September 2008 (left panel) and 2007 (right panel).

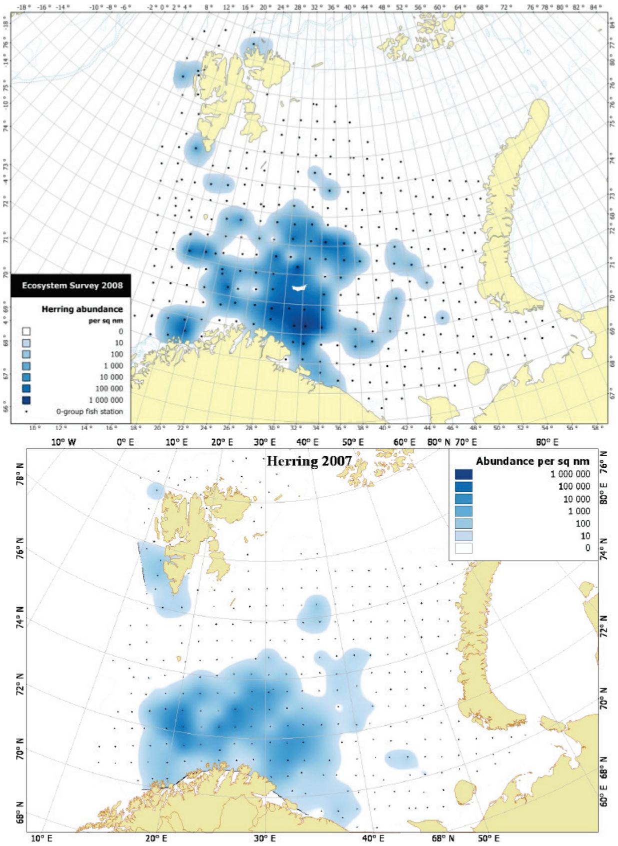

Figure B.3.5.2. NSSH O–group surveys in August/September in the Barents Sea in 2008 (left panel) and 2007 (right panel).

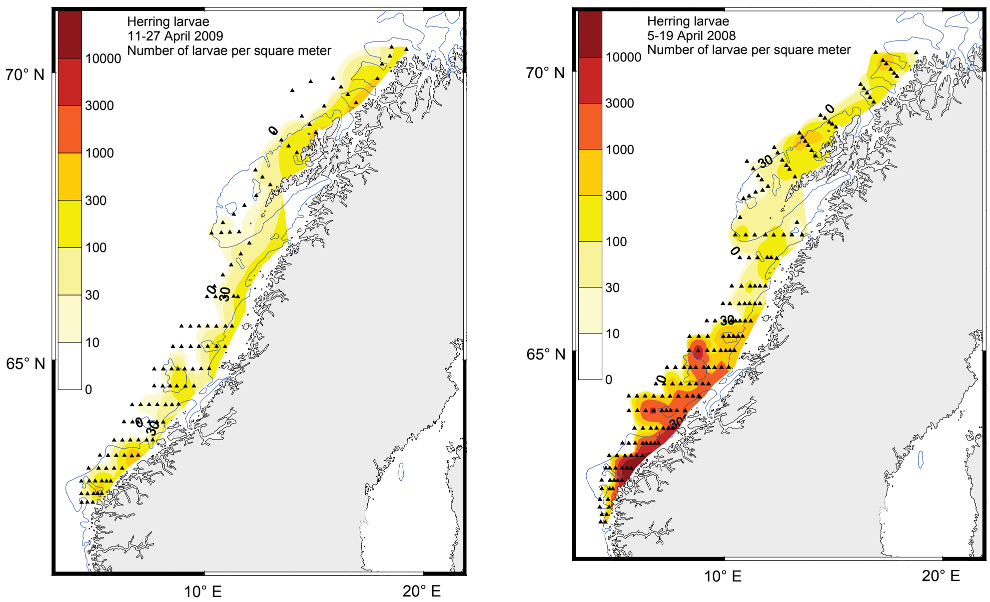

Figure B.3.6.1. NSSH. Distribution of herring larvae on the Norwegian shelf in 2009 (left panel) and 2008 (right panel). The 200 m depth line is also shown.

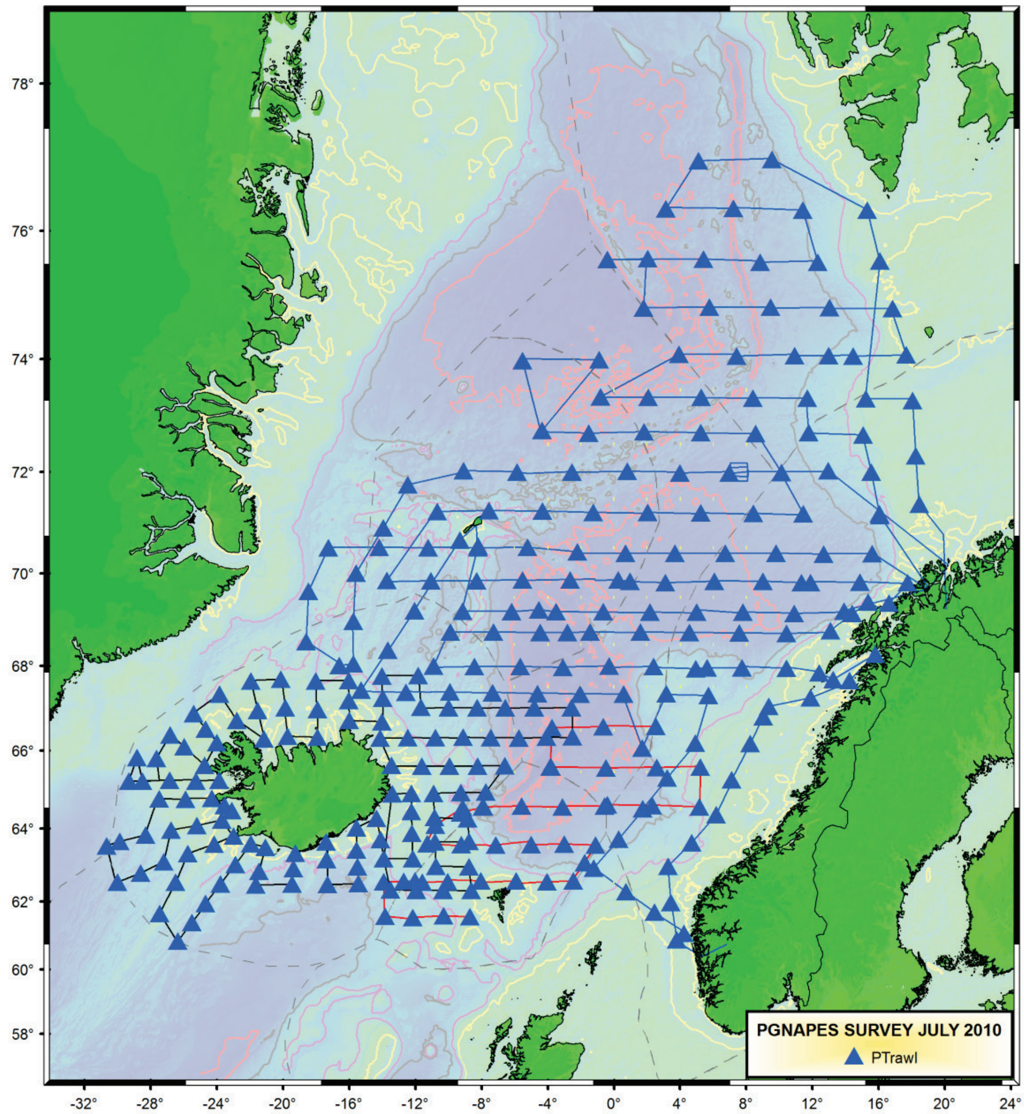

Figure B.3.7.1. Cruise tracks during the coordinated ecosystem survey in Norwegian Sea and adjoining waters in July-August 2010 and location of trawl stations.

Table 9.4.5.3 Herring in the Northeast Atlantic (Norwegian spring-spawning herring). Summary of the stock assessment. Data prior to 1988 are from the 2006 assessment year.

Year	Recruitment Age 0 thousands	SSB tonnes	Landings tonnes	F weighted Ages 5-14
1950	751000000	14200000	826000	0.0584
1951	146000000	12500000	1280000	0.0697
1952	96600000	10900000	1250000	0.0728
1953	86100000	9350000	1070000	0.0663
1954	42100000	8660000	1640000	0.1130
1955	25000000	9270000	1360000	0.0783
1956	29900000	10900000	1660000	0.1100
1957	25400000	9650000	1320000	0.1030
1958	23100000	8690000	986000	0.0787
1959	412000000	7180000	1110000	0.1130
1960	198000000	5850000	1100000	0.1360
1961	76100000	4390000	830000	0.1040
1962	19000000	3440000	849000	0.1460
1963	169000000	2670000	985000	0.2530
1964	93900000	2530000	1280000	0.2260
1965	8490000	3060000	1550000	0.2780
1966	51400000	2800000	1960000	0.6960
1967	3950000	1470000	1680000	1.5200
1968	5190000	344000	712000	3.4900
1969	9780000	145000	67800	0.5900
1970	661000	71000	62300	1.3200
1971	236000	32000	21100	1.5300
1972	957000	16000	13200	1.5000
1973	12900000	85000	7020	1.1700
1974	8630000	91000	7620	0.1140
1975	2970000	79000	13700	0.1900
1976	10100000	138000	10400	0.1060
1977	5100000	286000	22700	0.1110
1978	6200000	358000	19800	0.0434
1979	12500000	388000	12900	0.0238
1980	1470000	471000	18600	0.0341
1981	1100000	504000	13700	0.0215
1982	2340000	503000	16700	0.0200
1983	343000000	575000	23100	0.0291
1984	11500000	602000	53500	0.0903
1985	36600000	515000	170000	0.3790
1986	6040000	437000	225000	1.0700
1987	9090000	926000	127000	0.4040
1988	25724000	2768000	135301	0.045
1989	73988400	3409000	103830	0.029
1990	109705800	3702000	86411	0.022

Year	Recruitment Age 0 thousands	SSB tonnes	Landings tonnes	F weighted Ages 5-14
1991	320875600	3877000	84683	0.023
1992	383921700	3767000	104448	0.027
1993	121890400	3641000	232457	0.064
1994	42242100	4122000	479228	0.129
1995	18643900	4976000	905501	0.229
1996	57789400	6545000	1220283	0.192
1997	50575900	7887000	1426507	0.180
1998	282407700	7290000	1223131	0.153
1999	227356600	6852000	1235433	0.186
2000	54030800	5837000	1207201	0.213
2001	35695300	4794000	766136	0.180
2002	568142000	4928000	807795	0.184
2003	185261300	6298000	789510	0.114
2004	344513300	7149000	794066	0.094
2005	53536700	7715000	1003243	0.128
2006*	90770000	11580000	968958	0.131
2007*	30990000	11836000	1266993	0.098
2008**	103000000	12437000	1545656	0.125
2009**	103000000	13300000		
Average	100457748	4646433	690524	0.3220

*** Recruitment value has been replaced in the forecast by RCT estimate.**

**** GM mean 1989-2005**

Stock Annex 2D – Stock Annex Blue Whiting (Subareas I–IX, XII and XIV

Quality Handbook	**Blue whiting (Subareas I–IX, XII and XIV)**

Stock specific documentation of standard assessment procedures used by ICES.

Stock:	Blue Whiting
Working Group:	Working Group for Widely distributed stocks
Date:	Updated in February 2012.
Revised By:	Afra Egan *et al*. (1st version 2010), WKPELA 2012

A. General

A.1. Stock definition

Blue whiting (*Micromesistius poutassou*) is a pelagic gadoid that is widely distributed in the eastern part of the North Atlantic. The highest concentrations are found during spawning along the edge of the continental shelf in areas west of the British Isles and on the Rockall Bank plateau where it occurs in large schools at depths ranging between 300 and 600 meters but is also present in almost all other management areas between the Barents Sea and the Strait of Gibraltar and west to the Irminger Sea. Adults reach maturation at 2-7 years old and undertake long annual migrations from the feeding grounds to the spawning grounds (Bailey, 1982). Most of the spawning takes place between March and April, along the shelf edge and the banks west of the British Isles. Juveniles are abundant in many areas, with an important nursery area believed to be the Norwegian Sea, at least in times of high abundance. Morphological, physiological, and genetic research has suggested that there may be several components of the stock which mix in the spawning area west of the British Isles. Due to the large population size, its considerable migratory capabilities and wide spatial distribution, the stock composition and dynamics require continued monitoring. The migration routes of blue whiting in the north Atlantic are shown in Figure D1.

Blue Whiting Stock Identity

Prior to 1993, for the purposes of assessment, it was assumed that blue whiting had two components, a northern and a southern component. The Northern stock was known to feed in the Norwegian Sea and spawn to the west of the British Isles. The Southern stock was found along the continental shelf off the coast of Spain and Portugal with the main spawning areas towards the Porcupine Bank. The Porcupine Bank was considered a transitional area between the two main stocks (ICES, 1990). In 1993 it was argued that there was no strong evidence to maintain this division between the two stocks. Results from an otolith age reading workshop at that time showed no significant difference in mean annual ring diameter between northern and southern stocks. It was agreed by ACFM in 1993 that the two stocks should be combined for assessment purposes (ICES, 1995). Since then this stock has been assessed as one unit.

Several approaches have been employed to investigate the stock structure of blue whiting. The details of studies relating to genetics, larval otolith growth patterns and the movements of eggs and larvae have been published in recent years.

Blue Whiting have a wide geographic distribution and large population size, which is generally advantageous for the accumulation and preservation of genetic variability (Mork and Giaever, 1995). The first genetic work was carried out in the early 1990s. A study was carried out by Mork and Giaever, 1995 included samples from most of the eastern Atlantic but the amount of samples from the southern part of this area was generally low. Further work revealed significant geographic heterogeneity with reproductive units found at the fringes of the distribution range. A genetically distinct population was found in the Barents Sea and potential populations identified in the Mediterranean and Romsdalsfjord area of Norway. Samples taken from the area west of the British Isles and from the Norwegian Sea were genetically similar, which suggests a single blue whiting stock throughout the area (Giaever and Stein, 1998). Genetically distinct populations were also found in the Barents Sea and Mediterranean by Ryan *et al* 2005 by using one minisatellite and five microsatellite loci. Temporal variation was also seen between samples collected on the main spawning area. In this case there was insufficient data to identify explicitly the geographic range of these possible stocks. The most recent study conducted by Was *et al*, 2008 used a landscape genetics approach which combines spatial and genetic information to detect barriers to gene flow. This microsatellite analysis found that samples collected and analysed from along the south flowing current from the Porcupine Bank i.e. the Celtic Sea and Bay of Biscay were genetically different from those in the northward flowing current. Temporal variation was seen in samples collected in the Rockall Bank area and the reasons for this are inconclusive.

Oceanographic modelling has been used to examine movements of blue whiting eggs and larvae. Larval drift is an important factor in recruitment. A hypothesis put forward by Skogen *et al*, 1999, was that the southern stock will spawn in an area where the eggs and larvae are likely to drift southwards and the northern stock where the eggs and larvae will drift northwards. Based on modelled drift patterns they found that a possible separation line was located at 54.5ºN but this was subject to significant interannual variability over the twenty years studied. Work conducted by Bartsch and Coombs (1997) used a three dimensional baroclinic model suggests that particles released on the Porcupine Bank drifted southwards with a separation at about 53-54ºN. This work gave some additional information about stock separation but suggested that the division might be more southerly. Additional testing of the use of this type of model was recommended.

An investigation of larval growth histories was carried out in 2007 (Brophy and King, 2007). Groups that are spatially or temporally distinct after hatching show measurable differences in the larval portion of the otolith. This study has shown that larvae from the Bay of Biscay grow faster than those from more northerly spawning areas. It also confirmed that fish spawning to the west of Ireland and Scotland, do not form a randomly mixing unit and that subunits within this aggregation have experienced differences during the larval phase. It was hypothesised that the dispersal of larvae could influence the subsequent dispersal of spawning adults. The fish that are found in the feeding assemblages throughout the distribution may not contribute equally to the spawning assemblages in the north and south of the spawning grounds.

In 2009 the stock identification methods working group (SIMWG) stated that the perception of blue whiting in the NE Atlantic as a single unit stock is not consistent with recently observed differences in genetics and growth and should be revised; based on current available data. They recommended that a precautionary approach should initially treat blue whiting populations in areas VIIk and VIIj and further south as a separate unit from all other NE populations. SIMWG is in support of an initial, precautionary delineation of "two main stocks" but also vigorously suggests that a large, interdisciplinary project on this species is needed in order to comprehensively understand blue whiting stock structure in the NE Atlantic so that SIMWG may provide more robust advice (ICES, 2009a).

Recent results from length-at-age and otholith shape analysis presented in at WKPELA in 2012 (ICES, 2012?) did not provide evidence two separate stocks but rather substantial mixing of individuals on the common spawning grounds. At this meeting following a full review of available studies on blue whiting stock structure in the northeast Atlantic. The working group came to the conclusion that there is no scientific evidence in support of multiple stocks with distinct spawning locations or timings. The emerging picture is one of a single stock whose large scale spatial distriution varies as a function of hydrographic conditions and total abundance; this is commonly described as an abundance-occupancy relationship. Further, there seem to be a number of core nursery and feeding areas with marginal areas being occupied at times of high stock abundance. As a result, the working group decided to recommend treating blue whiting in ICES subareas I–IX, XII and XIV as a single stock for assessment purposes.

A.2. Fishery

Since 1988, 18 national fleets have been involved in the blue whiting fisheries. The highest landings have been reported by Norway, followed by the USSR/Russia, Iceland and the Faroes. Over the last decade, 13 or 14 national fleets land parts of the blue whiting quota each year. The highest concentrations of catches are generally found along the edge of the continental shelf in the area west of the British Isles, on the Rockall and Hatton Banks and around the Faroe Islands in quarter 1. In the following quarters catches are generally taken further north in the Norwegian Sea and also in the North Sea with lesser quantities of blue whiting caught in the southern area off Spain and Portugal.

Most of the catches are taken in the directed pelagic trawl fishery in the spawning and post spawning areas (Divisions Vb, VIa, b, and VIIb, c). Catches are also taken in the directed and mixed fishery in Subarea IV and Division IIIa, and in the pelagic trawl fishery in the Subareas I and II and in Divisions Va and XIVb. These fisheries in the northern areas have taken between 360,000–2,300,000 t per year in the last decade, while catches in the southern areas (Subarea VIII, IX, Divisions VIId, e and g–k) have been in the range of 20,000–85,000 t. The proportion of landings originating from the Norwegian Sea fluctuates greatly, having increased from 5% of the total in the mid-1990s to around 30% in 2003–2004, after which the proportion decreased again to below 10%. These fluctuations are thought to be linked to fluctuations in recruitment. In Division IXa blue whiting is mainly taken as bycatch in mixed trawl fisheries (ICES, 2008a). The proportions of landings originating in each area are mapped and presented in the annual working group reports.

The procedure of the working group is to split length frequency data into three areas, although it is recognised that the northern area comprises both spawning size fish and juveniles. The three areas are as follows:

1. The southern area around Spain and Portugal
2. The northern area which includes the spawning grounds and the Norwegian Sea
3. The North Sea and the Skagerrak.

A.3. Ecosystem aspects

The blue whiting stock has seen an almost threefold increase in spawning stock biomass since the mid 1990's. In recent years the stocks has declined in terms of spawning stock biomass and the year classes from 2005 and onwards are all poor. However, some signs of improved recruitment were observed from the two surveys in 2011 where young blue whiting were caught in the northern areas of the spawning stock survey in April (IBWSS) as well as in the May Ecosystem survey in the Nordic Seas (IESNS). Throughout this low period, recruitment strength in the Bay of Biscay and Celtic Sea seemed to have been high for the regions, indicating a anti-cyclic pattern. The early life stages have a significant influence on the reproductive success of this stock. The main blue whiting spawning areas are located along the shelf edge and banks west of the British Isles and Ireland. The eggs and larvae spawned on the Porcupine Bank area (west of Ireland) can drift both towards the south and towards the north, depending on the spawning location, oceanographic conditions and the effects from wind force, while the spawning products from the northern spawning area west of the Hebrides always drift northwards. The northward drift spreads the major part of the juvenile blue whiting to the Norwegian Sea and adjacent areas from Iceland, Faroes and North Sea to the Barents Sea. The larvae usually settle on the deeper areas of the various shelf-edges in the autumn and stay more or less associated with bottom the first winter or more, gradually becoming part of the mature stock after 2 or 3 years. Adult blue whiting carry out active feeding and spawning migrations in the same area as herring. Blue whiting has consequently an important role in the pelagic ecosystems of the area, both by consuming zooplankton and small fish, and by providing a food resource for larger fish and marine mammals (ICES, 2009b). However, a study by Utne *et al*. (in press 2012) suggest that the vertical overlap between blue whiting and herring/mackerel in the Norwegian Sea during the summer feeding period is limited as blue whiting prefer to stay in deeper waters than the other two species. These indicate that the food competition might be limited between blue whiting and mackerel/herring during the summer months in certain areas.

During the spawning stock survey on blue whiting in 2009, large amounts of mackerel were observed throughout the spawning grounds. The mackerel was distributed from 60-300 meters and fed heavily on pearlsides (*Maurolicus mülleri*) (PGNAPES, ICES RMC/06, 2009). The overlapping distribution of feeding mackerel within the blue whiting spawning grounds suggests a possible ecologic interaction between the two stocks, and predation from mackerel on blue whiting egg and larvae could be a contributing factor to the collapse in blue whiting recruitment observed. This interaction may have increased significantly both with the growth in the mackerel stock and with the changes observed in mackerel distribution in recent years. It is strongly suggested that investigations are carried out on this relationship in order to evaluate possible effects of mackerel on blue whiting recruitment.

Environmental conditions in the main spawning areas have undergone significant changes during this time. Changes in temperature, salinity and circulation have been recorded in long term trend data. Blue whiting are sensitive to temperature and salinity and will only spawn in waters with suitable ranges. Hatun *et al.* (2009a) suggests a temperature range of 9°-10°C and salinity ranges of between 35.35 and 35.45 psu.

The ICES report on ocean climate (ICES, 2008b) provides a summary of long term trends in environmental conditions until the end of 2007. Increases in temperature and salinity have been recorded over the blue whiting distribution area. An increase in sea surface temperature (SST) was shown at several of the monitoring stations in the NE Atlantic with temperatures up 3°C since the early 1980s (ICES, 2008c). Salinity has shown some fluctuations throughout the time series. In the Rockall trough salinity reached a peak in 2003 and has declined slightly since then. The same trend can be seen in the Faroes Shetland Channel. In the Norwegian Sea increases in both temperature and salinity have occurred since the mid 1990s (ICES, 2008b).

The circulation of the North Atlantic is characterized by two large gyres: the subpolar and subtropical gyre. Some of the water in the subtropical gyre is re-circulated to the west of the Mid Atlantic Ridge (MAR) and some water continues east and crosses the MAR in the Azores Current and the remainder forms the North Atlantic Current (NAC) (ICES 2008f). The subpolar gyre controls the flow trajectory of the NAC in the Northeastern Atlantic. When the gyre is strong, it extends eastwards, branches off and carries cold less saline water to the Rockall Trough and over the Rockall plateau (Figure D2a). When the gyre is weak it moves west and allows subtropical water to spread north and west and this results in warmer more saline conditions (Figure D2b) (Hatun, *et al.* 2009a).

Work carried out by Hatun, *et al.* 2007 used a gyre index value which is obtained from the simulated sea surface height over the entire North Atlantic Ocean and it reflects the shape and strength of the subpolar gyre. Since blue whiting are known to spawn in water masses with a relatively narrow temperature and salinity range the variability in the strength of the gyre index influences their spawning distribution. A strong gyre index is associated with cold and fresh conditions in the North East Atlantic and this seems to coincide with spawning to the east, along the continental slope and the Porcupine Bank area. The post spawning migration takes place in the Faroe Shetland channel and is possibly associated with a smaller total fish stock. When the gyre index is weak spawning takes place on the western slope of the Faroe plateau and over the Rockall plateau. The post spawning migration is also on the west through the Faroe Bank channel and is possibly leads to a larger stock size. The estimated threefold increase in blue whiting biomass coincided with major changes in the marine climate and this shift between east and west during the mid 1990s indicates a possible connection.

Hatun, *et al.* 2009a explored the hypothesis that the spawning distribution is predominantly controlled by the marine climate conditions west of Ireland, along the continental slope and west of Rockall when the subpolar gyre is weak and towards the Porcupine bank when the subpolar gyre is strong. This study used hydrographic, acoustic biomass and larval data as well as catch statistics and data from the regional gyre index. This study showed that the spawning distribution of blue whiting is determined by oceanographic conditions to the west of Great Britain and Ireland which in turn are regulated by the North Atlantic subpolar gyre.

Further work was carried out to examine large scale bio-geographical shifts in the northeast Atlantic from the subpolar gyre which used an ocean circulation model and data from four trophic levels including phytoplankton, zooplankton, blue whiting and pilot whales (Hatun, *et al.* 2009b). This study found that changes in the distribution of blue whiting are caused by variable stock size and by shifts in the migration pattern. The subpolar gyre influences this process either by:

1. Directly regulating the currents and or hydrographic conditions that will influence the migration routes

   or

2. Indirectly via trophodynamics.

This work suggests that recent advances in simulating the dynamics of the subpolar gyre may provide a potential for predicting the distribution of the main faunal zones in the north-eastern Atlantic a few years into the future. This in turn would facilitate more rational management of commercially important fish species.

Recruitment

A workshop was held in 2009 that examined blue whiting recruitment. The group reviewed and updated existing work on both the oceanography in the region and the distribution dynamics of blue whiting, particularly focusing on the most recent observations. A broad selection of hypothesizes were examined that may explain the recruitment dynamics of this stock. The group focused on two potential mechanisms that may account for the hypothesized links between the oceanographic climate and the recruitment dynamics.

1. The predation hypothesis

This hypothesis examines the role of mackerel predation and changes in the spawning distribution of blue whiting. Changes in the spawning distribution lead to changes in the mackerel-blue whiting larvae overlap, and therefore the degree of predation.

2. The food hypothesis

This hypothesis is based on the amount and availability of food to the larvae and juveniles. Changes in the oceanographic conditions may change the food availability and ultimately impact larval/juvenile growth, survival and recruitment. More research if required to examine these topics (ICES, 2009c, RMC:09)

Finally, the workshop examined potential schemes that could be used for generating recruitment forecasts. A high-degree of autocorrelation is present in the time-series, and indeed the assumption that recruitment in the following year is the same as the recruitment in the previous year was found to give relatively good predictions ($r2=0.57$). However, in the absence of a detailed process understanding, it was not possible to move beyond such basic schemes towards making genuine, knowledge-based, forecasts though qualitatively forecasts (high or low) might be feasible. Further research is required.

B. Data

B.1. Commercial catch

SALLOCL

Commercial catch data is obtained from national laboratories of nations exploiting blue whiting. Data exchange spreadsheets are submitted to the stock coordinator. Prior to 2009 the data in the exchange spreadsheets were allocated samples to catch using the SALLOCL-application (Patterson, 1998). This programme produced the standard outputs on sampling status and biological parameters. It also clearly documented any decisions made by the stock co-ordinators for filling in missing data and raising the catch information of one nation/quarter/area with information from another data set.

InterCatch

InterCatch which is a web-based system for handling fish stock assessment data was first used in 2009. Blue Whiting data are submitted using the 'Data Submission Workbook' spreadsheet and converted into the InterCatch format by the program "InterCatchFilemaker", developed by Andrew Campbell from Marine Institute, Galway, Ireland. The total International Catch-at-Age was available through the InterCatch web program. The allocations for those countries reporting catches without samples, were generally made using all available data for the same ICES Division and the same quarter. In cases where this was not possible, data from the nearest Divisions and the same quarter were used.

B.2. Biological Data

Sampling Protocol

In recent years all of the main countries participating in this fishery have provided sampling data to the working group. The European Commission Regulation 1639/2001 sets out the minimum and extended programmes for the collection of data in the fisheries sector and includes guidelines for blue whiting. This regulation requires EU Member States to take a minimum of one sample to be taken for every 1000 t landed in their country. Detailed information on the number of samples collected, number of fish aged and measured by year and by country is presented in the working group report (ICES, 2008a). This regulation applies to EU member states and there are currently no guidelines in place for other countries. Current precision levels of the sampling intensity are unknown and the group recommends reviewing the sampling frequency and intensity on a scientific basis and providing guidelines for sampling intensity.

Age Reading

The most recent age reading workshop took place in Hirtshals Denmark in June 2005. Guidelines for ageing blue whiting are outlined in this report and all of the workshop participants agreed to follow these guidelines. The workshop found that overall there was a high level of agreement between age readers. The two main reasons for disagreement between age readers were firstly the position of the first ring when the Bowers ring is clear and secondly true rings not counted by less experienced readers. Younger fish achieved better precision than older fish. This illustrates the problems associated with ageing older fish and is a common problem among many fish species (Worsøe Clausen, *et al* 2005).

An otolith exchange was carried out in 2009/2010 for a workshop in 2011. Age reading problems of 1 and 2 group blue whiting became evident during the 2011 May survey where small blue whiting was aged as 1, 2 or a combination of 1 an 2 years, pending on which country read the otoliths. This clearly demonstrates the need to calibrate the age-readings by each institute participating in the surveys.

Age composition in the catch

The catch numbers at age were mean standardised by year and are presented in Figure D3. Strong year classes can be seen in the past as they moved through the fishery. In recent years the numbers of fish at younger year classes are not as abundant and there are no signs of incoming strong recruitment.

Weight at age in the catch and Weight at age in the stock

Mean weight at age in the catch data are calculated on an annual basis from data supplied by Denmark, the Faroes, Iceland, Ireland, the Netherlands, Norway, Portugal, Russia, Scotland and Spain. Figure D4 shows the mean weight at age for the total catch from 1981–2009 which is used in the stock assessment in 2010.

Maturity

Maturity at age used in the assessment was obtained by combining maturity ogives from the southern and northern areas, weighted by catch in numbers at age (ICES, 1995). These values have been used since 1994. Although the values of maturity at age may be too low, sufficient information for estimating new ogives is not available.

Natural Mortality

It is known that blue whiting is a common prey amongst many different fish, cetacean and mammal predators. Defining how this impact varies over time is not a trivial issue for such a widely distributed stock that also exhibits notable changes in stock productivity over time. The current M of 0.2 was derived from investigations undertaken in the 1980s that examined the age distribution of the stock before the industrial fishery started. The possible need for revising the current estimate of instantaneous natural mortality rate *M* for blue whiting was discussed in detail by the 2002 WG (ICES, 2002). The value of M estimated from different methods was in the range of 0.38 to 0.60. Although it was acknowledged that the current estimate M =0.2 yr might be too low, there is not a strong basis for revision. At the WKPELA pelagic benchmark meeting, in 2012, various methods to attempt to estimate how M may vary over ages were explored. The relationship between natural mortality and body weight was applied to the blue whiting data to determine a variable M by age. The values ranged from around 1.1 at age 0 to 0.7 at age 10, which is considerably higher than the value used so far. Methodological work by WGMG (ICES, 2003a) emphasizes that natural mortality rate cannot be estimated reliably with information normally available for stock assessment models, so it is considered that further examination would be necessary in order to incorporate such values into the assessment. The effect a change in the assumed natural mortality in the assessment would have on assessment results would also need to be explored. At present it is considered that there is no new information to support a revision of the current estimate of M.

F and M before spawning

Both are set at 0, equivalent to spawning on the 1st January.

Discards

Discards of blue whiting are thought to be small. Most of the blue whiting caught in directed fisheries are used for reduction to fish meal and fish oil. However, some discarding occurs in the fisheries for human consumption and as bycatch in fisheries directed towards other species. Estimates of discarding are not included in the assessment. Reports on discarding from fisheries which catch blue whiting were available from the Netherlands for the years 2002–2007. A study carried out to examine discarding in the Dutch fleet found that blue whiting made a minor contribution to the total pelagic discards when compared with the main species mackerel, horse mackerel and herring (Figure D5). The length frequencies of landed and discarded fish caught were compared and from this data it is clear that herring and blue whiting are not selected and discarded for length reasons (Figure D6). It is more likely that in sorting and processing of mackerel small fish are commonly discarded (Borges, *et al* 2008).

Information on discards was available for Spanish fleets in 2006. Blue whiting is a bycatch in several bottom trawl mixed fisheries. The estimates of discards in these mixed fisheries in 2006 ranged between 23% and 99% (in weight) as most of the catch is discarded and only last day catch may be retained for marketing fresh. The catch rates of blue whiting in these fisheries are however low. In the directed fishery for blue whiting for human consumption with pair trawls, discards were estimated to be 13% (in weight) in 2006.

Since 2004, was available the blue whiting discards data produced by Portuguese vessels operating with bottom otter trawl within the Portuguese reaches of ICES Division IXa. The discards data are from two fisheries: the crustacean fishery and the demersal fish fishery. The blue whiting estimates of discards in the crustacean fishery for the period of 2004-2011 ranged between 23% and 40% (in metric tonnes). For the same period the frequency of occurrence in the demersal fish fishery was around zero for the most of the years, in the years were it was significant (2004, 2006, 2010) was ranged between 43% and 38% (in metric tonnes).

In general, discards are assumed to be minor in the blue whiting directed fishery. Discard data are provided by the Netherlands to the working group. Blue whiting is also by catch in several Spanish bottom trawl mixed fisheries. However, the catch rates of blue whiting in these fisheries are low (ICES, 2008a). French bottom trawl fisheries also catch blue whiting; discard estimates should become available in 2012.

B.3. Surveys

A number of surveys are (or have been) carried out which provide data on blue whiting abundance in different areas of their distribution. One survey is used to tune the assessment. The remaining surveys are not used in the assessment but data are updated on an annual basis and could be incorporated at a later stage should further work suggest their inclusion would lead to an improvement in the assessment.

Surveys Used in the assessment

1. International Blue Whiting spawning stock survey (IBWSS)

The IBWSS is carried out in March-April on the spawning grounds to the west of the British Isles and was established in its current form in 2004. Five countries participate annually in the survey; the Russian Federation, Norway, Faroes, the Netherlands and Ireland. The survey is internationally coordinated through the Working Group of International Pelagic Surveys (WGIPS).

The design of the IBWSS has traditionally been aimed at reducing the effects of double counting of the northward migrating spawning aggregation. Consideration is also given to the start and end times of the survey window to assure a synoptic coverage while taking into account vessel availability in the different countries and temporal occurrence of spawning aggregations. The spatial confines of the survey, although not fixed, are defined as core spawning areas and secondary target areas as suggested in 2005. The overall design uses stratified transects with a random start (random latitude) to ensure transect coverage is not replicated but randomised between years. The survey procedures are described in the "Manual for Acoustic Surveys on Norwegian Spring-spawning Herring in the Norwegian Sea and Acoustic Surveys on Blue whiting in the Eastern Atlantic" (ICES, 2008). The main problem affecting the outcome of the survey relates to adverse weather conditions encountered in the Northeast Atlantic at the time of the survey. This survey was first used as a tuning series in the assessment in 2007 with ages 3-8.

During the 2011 WGWIDE working group meeting it was decided to exclude the 2010 values from the IBWSSS time series on the basis of a recommendation from WGNAPES. During the 2010 survey, poor weather and a mismatch between vessels led to a gap in coverage in north Porcupine and south Hebrides (ICES CM2010/SSGESST:20). It was agreed within WGNAPES in 2010 that the gap in area coverage occurred in an area of concentrated fishing effort and thus contained a high but un-quantified biomass. Mean acoustic density for the un-surveyed rectangles within the core spawning area was determined by means of interpolation from surrounding surveyed rectangles following established methods. It was also agreed that the gap in coverage had no doubt resulted in an underestimate of the stock. However, the revised estimate was recommended to be accepted by WGWIDE in 2010 as the best available. In WGNAPES 2011(ICES CM2011/SSGESST:16) the time series was reviewed and the problems in the 2010 IBWSS was considered. The updated survey time series, including the 2011 survey, show a decline in the observed stock but the rate of decline is not as abrupt if the 2010 estimate is excluded. Due to the large uncertainties in the estimate from 2010, WGNAPES recommended to exclude the 2010 data from the time series in the assessment.

The original TS-length relationship applied for blue whiting was considered too low and tended to overestimate the abundance of fish. This original relationship was based on measurements taken from a juvenile cod in the 1970s and was applied as the best estimate available at the time. Acoustic abundance estimates of blue whiting have so far tended to be considerably higher than those based on the assessment. The Workshop on implementing a new TS relationship for blue whiting abundance estimates (WKTSBLUES) met in 2012. The objectives of the workshop were to implement a new TS-Length relationship proposed by Pedersen *et al*. (2011). This latest research used in-situ acoustic measurements and was taken over several years, utilizing several different observation platforms. As the measurements were taken during the spawning stock survey they are not only species-specific but also time and area specific, something which was not achieved with the old TS-length relationship. Recalculating the survey index resulted in an expected downward shift to around 32% of the original TSB. When recalculating the survey index all previous settings were retained to ensure continuity and comparability across the index. During the review of survey data an error was observed in the presented 2009 blue whiting estimate relating to abundance at age data. This error was corrected in the data in 2012.

2. International ecosystem survey in the Nordic Seas (IESNS)

An international ecosystem survey is carried out annually in the Nordic Seas from late April to early June aimed at observing the pelagic ecosystem in this area. This survey focuses on Norwegian spring spawning herring, blue whiting, zooplankton and hydrography.

The survey area was split into three subareas which are as follows:

Area I - Barents Sea

Area II - northern and central Norwegian Sea

Area III - Southwestern area, i.e. Faroese and Icelandic zones and Southwestern part of the Norwegian Sea

The survey is coordinated by WGIPS. Ages 1-2 from this survey were used as recruitment indices, but WKPELA2012 decided not to use any recruitment series in the assessment.

3. Norwegian survey on the spawning grounds

The Norwegian survey on the spawning grounds for blue whiting, west of the British Isles, provides the longest time series covering a significant part of the blue whiting stock, and is an important time series for tuning the assessment. This survey was carried out from 1991-2006. The time series from 1991 – 2003, ages 3-8 is currently used to tune the assessment. This survey was replaced by the International spawning stock survey.

Surveys not used in the assessment but provide information

4. Norwegian bottom trawl survey in the Barents Sea

Norway has conducted bottom trawl surveys targeting cod and other demersal fish in the Barents Sea since late 1970s. From 1981 onwards there have been systematically designed surveys carried out during the winter months (usually late January ‐ early March) by at least two Norwegian vessels; in some years the survey has been conducted in co ‐ operation with Russia. Blue whiting is a regular bycatch species in these surveys, and has in some years been among the numerically dominant species (Heino *et al,* 2003). This survey is presently giving the first reliable indication of year class strength of blue whiting. The survey is not used in the assessment because of it coverage at the edge of the distribution area, but it is used for recruitment predictions. The indices of 1 group blue whiting are presented in Table D1.

5. Spanish bottom trawl survey

Bottom trawl surveys have been conducted off the Galician (NW Spain) coast since 1980, following a stratified random sampling design and covering depths down to 500 m. The survey is directed to a mixture of species. Since 1983, the area covered in the Spanish survey was extended to completely cover Spanish waters in Division VIIIc. A new stratification has been established since 1997. The survey is not used in the assessments as it is only representative for a small part of the stock area. The mean catch and standard error of these bottom trawl surveys are presented in Table D2 and Figures E7. The stratified mean catch is presented in Figure D8.

6. Portuguese bottom trawl survey

Bottom trawl surveys have been conducted off the Portuguese coast since 1979, following a stratified random sampling design and covering depths down to 500 m. The area covered in the Portuguese survey was extended in 1989 to the 750 m contour. The survey is not used in the assessments as it is only representative for a small part of the stock area. The mean catch and standard error of these surveys is presented in Table D3.

7. French bottom trawl survey

Bottom trawl surveys have been carried out since 1987 in the Bay of Biscay and 1997 in the Celtic Sea following a random stratified sampling design and covering depths down to 700 m; both areas are covered in October-November. Estimates of aged 0 blue whiting using a cut off of 18 cm and raised to the total survey areas are presented in Table D5.

8. Irish bottom trawl survey

The current bottom trawl survey has been carried out since 2003 in October-November around Ireland using a stratified design (the design changed in 2005). Estimates of age 0 using a 18 cm cut off point are shown in Table D6.

7. Other Surveys

Several other surveys have in the past provided data to the Working Group. In recent years however these data have not been updated. Historical results from the following surveys are presented in WGNPBW working group reports.

- Norwegian Sea summer survey carried out in 1981 – 2001, 2005 – 2007. The stock estimates in numbers at age are given in the 2007 report.
- Faroes plateau spring bottom trawl survey carried out in March 1996–2008. The survey is aimed at cod, haddock and saithe, but varying amounts of blue whiting are caught as bycatch each year.
- Faroes plateau autumn bottom trawl survey carried out in August- September 1994–2008. The survey is aimed at cod, haddock and saithe, but varying amounts of blue whiting are caught as bycatch each year.

B.4. Commercial CPUE

Spanish pair trawl CPUE

The Spanish pair trawls CPUE series was used for several years as a tuning fleet in the blue whiting assessment. Following a recommendation of the methods working group (ICES, 2003) the use of this CPUE data was discontinued because this fleet represents only a small part of the landings caught in a small part of the distribution area. This data series runs from 1983-2003 and has not been updated since then. The age stratified CPUE data are shown in Table 4 and Figure 9 and show a slight declining trend in CPUE.

Norwegian CPUE

CPUE data in the spawning area was collected from the Norwegian commercial fleet 1982–2003. The time series has not been updated in recent years. The data are not considered to be representative for the development of the stock and are not used in the assessment.

B.5. Other relevant data

None.

C. Assessment Method and Data

Model used:

The State-space Assessment Model (SAM), analytical assessment.

At the Benchmark (WKPELA, 2012) the state-space models SAM model was chosen as the assessment model for blue whiting. SAM offers a flexible way of describing the entire system, with relative few model parameters. Compared to the previously used SMS model, SAM models fishing mortality from random walk, whereas SMS assumes a separable model for fishing mortality and thereby a rather stable exploitation pattern. Model diagnostics from both models for are similar; however SAM gives a slightly better fit to catch data as it allows variations in exploitation pattern from year to year. The assessment output from the two models is almost identical, such that the perception of the stock remains unchanged using SAM.

Software used:

Source code for the SAM model and all scripts are freely available at http://130.226.135.24/bluewhiting [Username: guest; Password: guest]. This web-page does also provide the latest assessment, including input and output.

Model Options chosen:

The blue whiting assessment makes use of one survey index (International Spawning Ground survey, IBWSSS) is used, and the total catch-at-age data. Fishing mortality random walks are allowed to be correlated.

The table below present the SAM configuration options (file model.cfg). In the file text following a hash-mark ("#") is a comment

```
# Min, max age represented internally in model
 1 10
# Max age considered a plus group? (0 = No, 1= Yes)

# Coupling of fishing mortality STATES
# 1 2 3 4 5 6 7 8 9 10 # Age
  1 2 3 4 5 6 7 8 9 9 # catch
  0 0 0 0 0 0 0 0 0 0 # IBWSSS

# Use correlated random walks for the fishing mortalities
# ( 0 = independent, 1 = correlation estimated)

# Coupling of catchability PARAMETERS
# 1 2 3 4 5  6  7  8 9 10 # Age
  0 0 0 0 0  0  0  0 0  0 # catch
  0 0 1 2 3  3  3  3 0  0 # IBWSSS

# Coupling of power law model EXPONENTS
# 1 2 3 4 5 6 7 8 9 10 #
  0 0 0 0 0 0 0 0 0 0 # catch
  0 0 0 0 0 0 0 0 0 0 # IBWSSS

# Coupling of fishing mortality RW VARIANCES
# 1 2 3 4 5 6 7 8 9 10 #
  1 1 1 1 1 1 1 1 1 1 # catch
  0 0 0 0 0 0 0 0 0 0 # IBWSSS

# Coupling of log N RW VARIANCES
# 1 2 3 4 5 6 7 8 9 10 #
  1 2 2 2 2 2 2 2 2 2

# Coupling of OBSERVATION VARIANCES
```

```
# 1  2  3  4  5  6  7  8  9  10 #
  1  2  3  3  3  3  3  3  4  4 # catch
  0  0  5  6  6  6  7  7  0  0 # IBWSSS

# Stock recruitment model code (0=RW, 1=Ricker, 2=BH)
 0
# Years in which catch data are to be scaled by an estimated parameter
(mainly cod related)
 0
# Fbar range
 3 7

# so called checksum
123 123
```

The options for "Coupling of fishing mortality STATES" show that random walk for F is independent by age for the ages 1-8, and combined for age 9 and 10.

It is assumed that F at age is correlated to some degree estimated by the models. Therefore the option for "Use correlated random walks for the fishing mortalities" is set to 1.

The "Coupling of catchability PARAMETERS" specifies the grouping of ages with respect to survey catchability. For the IBWSSS survey there is assumed an age dependent catchability for age 3 and 4, and a combined (the same) catchability ages 5-8.

In the IBWSSS a linear relation between CPUE and stock size is assumed, such that the options for "Coupling of power law model EXPONENTS" are all set to 0.

The variance for the random walk for F ("Coupling of fishing mortality RW VARIANCES ") is assumed the same for all ages.

The "Coupling of OBSERVATION VARIANCES" specifies the options for observation noise for both catches and survey indices. For catches the observation variance is age dependent for age 1 and 2. For ages 4-8 the variance is assumed the same, and different from the variance for ages 9-10. For the IBWSSS survey the variance is the the same within the groups of age 3, 4-6, and 7-8.

There is no obvious relation between SSB and recruitment, but recruitment seems to be correlated between years. To reflect this, the "Stock recruitment model code" is set to 0=Random Walk.

SAM is a new model which has not been applied to blue whiting before. Small changes in model structure may be applied following the first WGWIDE assessment of the stock using this model. In particular, to be able to effectively handled large changes in F in the terminal year (as may happen with the low 2011 TAC) an alternative variance distribution may be required for the random walk on F (e.g. t-distribution).

Input data types and characteristics:

Type	Name	Year range	Age range	Variable from year to year Yes/No
Caton	Catch in tonnes	1981 –	1-10	Yes
Canum	Catch at age in numbers	1981 –	1-10	Yes
Weca	Weight at age in the commercial catch	1981 –	1-10	Yes
West	Weight at age of the spawning stock at spawning time.	1981 –	1-10	Yes
Mprop	Proportion of natural mortality before spawning	1981 –	NA	No
Fprop	Proportion of fishing mortality before spawning	1981 –	NA	No
Matprop	Proportion mature at age	1981 –	1-10	No
Natmor	Natural mortality	1981 –	NA	No

Tuning data:

Type	Name	Year range	Age range
Tuning fleet 1	International Spawning Stock Survey	2004 – assessment year + 1	3-8

Models used for exploratory assessments

Previous WGWIDE working groups have conducted alternative assessments (e.g. TISVPA and XSA) in addition to the accepted assessment as a check on model assumptions and how the different model platforms handle the data. At future meetings exploratory analyses, potentially also including recruitment indices, will be encouraged. Advice will be based on the outputs of the SAM model.

D. Short-Term Projection

Model used:

Due to the uncertainty in the final year estimates of fishing mortality and stock numbers, the standard (deterministic) short-term forecast is considered inappropriate for this stock. Therefore, stochastic projections are performed, from which short-term projections are extracted. The stochastic projections are carried out by starting at the final year's estimates, using the variance-covariance matrix of those estimates. To run the short term forecast 1000 samples are generated from the estimated distribution of the final years estimates. Those 1000 replicates are then simulated forward according to the model and subject to different scenarios.

Software used:

Source code for the SAM model and all scripts including forecast script are freely available at http://130.226.135.24/bluewhiting [Username: guest; Password: guest].

Initial stock size: Final year's estimates, using the variance-covariance matrix of those estimates to generate replicates within the confidence bounds.

Maturity: The proportion mature for this stock is assumed constant over the years. The maturity ogive used in the short term forecast is the same as the ogive used in the assessment.

F and M before spawning: These values are both 0, spawning is assumed to take place the 1st January.

Weight at age in the stock and weight at age in the catch: Weight at age in the catch and weight at age in the stock are the same and for the short term forecast are calculated as three year averages.

Exploitation pattern: This is based on F in the year where the final three years of data calculated from the most recent assessment.

Natural Mortality: Natural mortality is assumed to be 0.2 across all ages. Maturity:

Intermediate year assumptions: TAC is landed fully.

Stock recruitment model used: None. Due to potential additional information affecting recruitment (qualitative use of recruitment indices, environmental impacts), the terminal stock estimate for age 1 and age 2 could optionally be raised by an input factor (the precise method by which this could be implemented has not been decided on.

E. Medium-Term Projection

Medium term projections were carried out as part of the management plan evaluation simulations at a meeting in May 2008 (Anon, 2008). These simulations were updated at WGWIDE in September 2008. HCS (Skagen, 2008) with some minor modifications were made to cover the needs of the blue whiting simulations. As a control, some simulations were repeated with the SMS software which is also used to assess the stock of blue whiting and was used for evaluation of the management plan presently in use (ICES, 2008a).

A new management plan evaluation will be conducted in 2012, scheduled for completion prior to WGWIDE 2012.

F. Long-Term Projections

Long term projections are not carried out for this stock.

G. Biological Reference Points

	Type	Value	Technical basis
Management plan	SSB_{MP}	2.25 million t	B_{pa}
	F_{MP}	0.18	Management strategy evaluation conducted in 2008 (Anon, 2008; ICES, 2008)
MSY Approach	MSY $B_{trigger}$	2.25 million t	B_{pa}
	F_{MSY}	0.18	Management strategy evaluation conducted in 2008 (Anon, 2008; ICES, 2008)
Precautionary Approach	B_{lim}	1.50 million t	B_{loss}
	B_{pa}	2.25 million t	B_{lim} exp(1.645*σ), with σ = 0.25.
	F_{lim}	Not defined	
	F_{pa}	Not defined	

The Workshop on Limit and Target Reference Points (WKREF) considered the biological reference points for Blue Whiting at a meeting in Gdynia, Poland in January in 2007 (ICES, 2007b). The original reference points for this stock were set in 1998, before the era of high productivity became apparent. The group examined the consequences of these new observations on the reference points by first splitting the time ‐ series into two productivity regimes (low productivity from 1981–1994, and high productivity from 1995–2005). Standard methods (i.e. using the guidelines from the Study Group on Precautionary Reference points, SGPRP (ICES, 2003b) were then used to re ‐ estimate the reference points, which were found to be comparable to the current values. A new probabilistic approach for estimating B_{lim} was also employed, but again, the result was found to be comparable with the current values. The group concluded that there was no basis for revising the current reference points. WKREF also noted that there may be no need for different B_{lim} values in different productivity regimes.

A stochastic equilibrium analysis made during the Working Group established by the Blue Whiting Coastal States on Blue Whiting management strategies (Anon, 2008) indicates a high risk of stock collapse with an F from approximately 0.3 and upwards given the “low recruitment” regime as observed in 1981–1996. F_{max} is poorly defined and a very limited increase in yield is obtained for F in the range 0.18 to 0.30. $F_{0.1}$ was estimated at 0.18. Sensitivity analysis of a change in exploitation pattern showed that these conclusions are robust with respect to the choice of exploitation pattern. A yield per recruit analysis was conducted using MFYPR which also calculated $F_{0.1}$ as 0.18.

At the WKPELA 2012 meeting the precautionary approach fishing mortality reference points for this stock were removed. A major problem was that fishing at F_{pa} implied a high probability of bringing the stock below B_{pa}, in other words the present combination of F_{pa} and B_{pa} is inconsistent, likewise for F_{lim} and B_{lim}.

Reference points for this stock may be revised in 2012 following the results of the long/medium term simulations of the blue whiting stock from the management strategy evaluation.

H. Other Issues

Changes in Blue Whiting Mean Weights over time

Possible causal relations for the visible reductions in mean weight at age were investigated by WGWIDE in 2008. Several aspects relating to the biology of fish stocks such as recruitment, growth or natural mortality, are influenced by ecosystem conditions. Some of these conditions were suggested as possible reasons for the change in mean weight at age. These include the following:

Density dependant competition– too many fish competing for the same food resource.

Changes in plankton abundance would impact on the amount of food available for blue whiting.

External environmental factors, such as temperature and salinity. Spawning is effected by both of these environmental variables.

An in depth analysis of the causes of these changes in mean weights, which would be needed for any kind of forecast is outside the scope of this working group (ICES, 2008a)

Possible effects of protecting juvenile Blue Whiting

The modern blue whiting fishery developed during the second half of the 1970s when the landings increased from around 100 000 tonnes to above 1 million tonnes. The majority of the catches have since been taken on the spawning grounds west of the British Isles. A small but fairly constant fraction of the catches are taken in the southern areas and in the North Sea (Norwegian trench) and a variable fraction in the Norwegian Sea (Figure D10). The proportion of landings taken in the Norwegian Sea increased after the strong year classes from 1995 onwards led to increased densities of (young) blue whiting in this area, but is now decreasing and was in 2007 around the pre-2000 level.

Landings from the Norwegian Sea and the North Sea are generally comprised of a higher proportion of juvenile fish compared to landings from the spawning area, though this proportion varies between years. A measure to reduce the exploitation of juveniles could therefore, in theory, be to close the fishery in these areas (or a temporal closure of the fishery outside the spawning season). However, it is impossible to estimate the resulting reduction in juvenile fishing mortality of such measures since juveniles are also exploited in the spawning ground fishery.

The effects on the yield per recruit curve of applying three different exploitation patterns on ages 1–2 were explored using the standard ICES software MFYPR; (1) zero exploitation, (2) "high" exploitation and (3) the constant F selection pattern used in SMS from 1999 onwards. The "high" exploitation pattern which gave the highest relative fishing mortality on ages 1–2 during the last 15 years was derived from the XSA assessment. The SMS exploitation pattern was used on ages older than 2 years. Figure D11 shows the three F selection patterns used and the resulting yield per recruit curves. The difference between the curves is marginal with similar values for $F_{0.1}$ derived. The conclusion is that the effect on yield of protecting juveniles is likely to be very small. A separate clause for the protection of juveniles in the management plan is not needed (ICES, 2008a).

H.1 Management and ICES advice

Management plans

A management plan was agreed for this stock between the four coastal states (Norway, Faroe Islands, Iceland, and EU) in December 2005. The text for the agreed plan is given below. This management agreement aims to maintain the SSB of the blue whiting stock at levels above 1.5 million tonnes (B_{lim}) and the fishing mortality rates at levels of no more than 0.32 (F_{pa}). To achieve this, the TAC is reduced by at least 100 000 t a year until the fishing mortality is reduced to 0.32 (F_{pa}). The plan states that if the spawning stock falls below 2.25 million t unspecified actions to obtain a safe and rapid recovery to this level should be taken. ICES has evaluated this management plan in 2006 and found it not to be in accordance with the precautionary approach in a period of low recruitment.

<u>Text for the 2005 management plan for Blue Whiting</u>

1) *The Parties agree to implement a multi-annual management arrangement for the fisheries on the blue whiting stock which is consistent with the precautionary approach, aiming at constraining harvest within safe biological limits, protecting juveniles, and designed to provide for sustainable fisheries and a greater potential yield, in accordance with advice from ICES.*

2) *The management targets are to maintain the Spawning Stock Biomass (SSB) of the blue whiting stock at levels above 1.5 million tonnes (Blim) and the fishing mortality rates at levels of no more than 0.32 (Fpa) for appropriate age groups as defined by ICES.*

3) *For 2006, the Parties agree to limit their fisheries of blue whiting to a total allowable catch of no more than 2 million tonnes.*

4) *The Parties recognise that a total outtake by the Parties of 2 million tonnes in 2006 will result in a fishing mortality rate above the target level as defined in Paragraph 2. Until the fishing mortality has reached a level of no more than 0.32, the Parties agree to reduce their total allowable catch of blue whiting by at least 100 000 tonnes annually.*

5) *When the target fishing mortality rate has been reached, the Parties shall limit their allowable catches to levels consistent with a fishing mortality rate of no more than 0.32 for appropriate age groups as defined by ICES.*

6) *Should the SSB fall below a reference point of 2.25 million tonnes (Bpa), either the fishing mortality rate referred to in Paragraph 5 or the tonnage referred to in Paragraph 4 shall be adapted in the light of scientific estimates of the conditions then prevailing. Such adaptation shall ensure a safe and rapid recovery of the SSB to a level in excess of 2.25 million tonnes.*

7) *This multi-annual management arrangement shall be reviewed by the Parties on the basis of ICES advice*

The stock is currently in a period of low recruitment. In July 2008 a new draft management plan was proposed by the Coastal States. ICES has evaluated the draft management plan and considers it precautionary if fishing mortality in the first year is immediately reduced to the fishing mortality that is implied by the HCR. The text of this plan is also presented below.

<u>Text for the 2008 management plan for Blue Whiting</u>

1) The Parties agree to implement a long term management plan for the fisheries on the Blue Whiting stock, which is consistent with the precautionary ap-

proach, aiming at ensuring harvest within safe biological limits and designed to provide for fisheries consistent with maximum sustainable yield, in accordance with advice from ICES.

2) For the purpose of this long term management plan, in the following text, "TAC" means the sum of the coastal State TAC and the NEAFC allowable catches.
3) As a priority, the long term plan shall ensure with high probability that the size of the stock is maintained above 1.5 million tonnes (B_{lim}).
4) The Parties shall aim to exploit the stock with a fishing mortality of 0.18 on relevant age groups as defined by ICES.
5) While fishing mortality exceeds that specified in paragraph 4 and 6, the Parties agree to establish the TAC consistent with reductions in fishing mortality of 35% each year until the fishing mortality established in paragraph 4 and 6 has been reached. This paragraph shall apply only during 2009 and 2010.
6) For the purposes of this calculation, the fishing percentage mortality reduction should be calculated with respect to the year before the year in which the TAC is to be established. For this year, it shall be assumed that the relevant TAC constrains catches.
7) When the fishing mortality in paragraph 4 has been reached, the Parties agree to establish the TAC in each year in accordance with the following rules:

   In the case that the spawning biomass is forecast to reach or exceed 2.25 million tonnes (SSB trigger level) on 1 January of the year for which the TAC is to be set, the TAC shall be fixed at the level consistent with the specified fishing mortality.

   In the case that the spawning biomass is forecast to be less than 2.25 million tonnes on 1 January of the year for which the TAC is to be set (B), the TAC shall be fixed that is consistent with a fishing mortality given by:

$$F = 0.05 + [(B - 1.5)(0.18 - 0.05) / (2.25 - 1.5)]$$

   In the case that spawning biomass is forecast to be less than 1.5 million tonnes on 1 January of the year for which the TAC is to be set, the TAC will be fixed that is consistent with a fishing mortality given by F = 0.05.

8) When the fishing mortality rate on the stock is consistent with that established in paragraph 4 and the spawning stock size on 1 January of the year for which the TAC is to be set is forecast to exceed 2.25 million tonnes, the Parties agree to discuss the appropriateness of adopting constraints on TAC changes within the plan.
9) The Parties, on the basis of ICES advice, shall review this long term management plan at intervals not exceeding five years and when the condition specified in paragraph 4 is reached

In 2012 options for a new management plan will be explored.

ICES advice

In 2003, ICES stated that both estimates of SSB and fishing mortality were high but uncertain. Nevertheless, the spawning stock biomass in 2003 was likely to be above B_{pa}. Therefore, based on the most recent estimates of fishing mortality and SSB, ICES classified the stock as likely to be harvested outside safe biological limits ($F>F_{lim}$). The incoming year classes seemed to be strong. ICES recommended that catches should be less than 925 000 tonnes in 2004 in order to achieve a 50% probability that the fishing mortality in 2004 is less than F_{pa} (=0.32). This would also assure a high probability that the spawning stock biomass in 2005 to be above B_{pa} (ICES, 2005).

In 2004 ICES concluded from the most recent estimates of fishing mortality and SSB, that the stock had full reproductive capacity, but was harvested unsustainably. Although the estimates of SSB and fishing mortality were not considered precise, it was certain that SSB was above B_{pa} and the estimated fishing mortality well above F_{lim}. Recruitments in the last decade appeared to be at a much higher level than earlier. The unimplemented management plan implied catches of less than 1.075 million t in 2005 which was expected to keep fishing mortality less than 0.32 with 50% probability. This would also have assured a high probability that the spawning stock biomass in 2006 would be above B_{pa}. ICES recommended that measures be taken to protect juveniles (ICES, 2005).

In 2005 ICES advised that fishing within the limits of the management plan (F=0.32) implied catches of less than 1.5 million t in 2006. This would result in a high probability that the spawning stock biomass in 2007 would be above B_{pa}. The present fishing level was well above levels defined by the management plan and should be reduced. The primarily approach to reduce catch of juveniles is to reduce overall fishing mortality. Catches of juveniles in the last 4 years were much greater than in earlier periods. If an overall reduction of fishing mortality cannot be achieved then specific measures should be taken to protect juveniles (ICES, 2006a).

In 2006 ICES stated that the maximum catch in 2007 corresponding to a new agreed management plan is 1.9 million tonnes, which is expected to leave the spawning stock biomass at 2.86 million t, i.e. above B_{pa} in 2008, but would lead to an F above F_{lim} in 2007. Fishing mortality is estimated at 0.48 and was above the fishing mortalities expected to lead to high long-term yields and low risk of depletion of production potential. Fishing at F_{pa} implies catches of less than 980 thousand t in 2007. This was expected to result in a spawning stock biomass in 2008 well above B_{pa}. The newly agreed management plan was evaluated by ICES and was not considered in accordance with the precautionary approach. ICES concluded that the exploitation boundaries for this stock should be based on the precautionary limits (ICES, 2007a).

In 2007 ICES classified the stock as having full reproductive capacity, but being harvested at increased risk. SSB increased to a historical high in 2003, but has decreased since then. The estimated fishing mortality was well above F_{pa}. Recruitment in the last decade appears to be at a much higher level than prior to 1996. The 2005 and 2006 year classes were estimated at the pre 1996 level. ICES has evaluated the present management plan in 2006 and found it not to be in accordance with the precautionary approach. ICES concluded that the exploitation boundaries for this stock should be based on the precautionary limits. The advice for 2008 is a maximum TAC at 835 000 t based on an F at F_{pa} (ICES, 2008a).

The 2008 advice for Blue whiting states that based on the most recent estimates of fishing mortality and SSB, ICES classifies the stock as having full reproductive capacity, but being harvested at increased risk. SSB increased to a historical high in 2003, but has decreased since then and is expected to be just above B_{pa} in 2009. The estimated fishing mortality is well above F_{pa}. Recruitment of the 2005 and 2006 year classes are estimated to be in the very low end of the historical time-series. Surveys indicate that the 2007 year class could also be low.

In 2009 ICES advised that based on the most recent estimates of SSB (in 2009) and, fishing mortality (in 2008), ICES classifies the stock as having full reproductive capacity and being harvested sustainably (F=0.29). Year classes 2005-2008 are among the lowest observed. Due to recent low recruitment, SSB has declined from its historical peak in 2003-2004 of more than 7 million tonnes to 3.6 million tonnes at the beginning of 2009, and the decline is expected to continue in the short-term.

In 2010, following a sharp downward revision in the perceived abundance of the stock in the assessment, the TAC for blue whiting in 2011 was significantly lower than in 2010. This downward revision in the assessment estimates of abundance was driven predominantly by the low values of the 2010 IBWSSS acoustic survey. In 2011 these values were removed from the assessment of the stock (see Section B.3) resulting in an upward revision of abundance estimates. This lead in turn to a sharp increase in the TAC for 2012 compared with the low 2011 TAC.

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Table D1: 1-group indices of blue whiting from the Norwegian winter survey (late January-early March) in the Barents Sea. (Blue whiting <19cm in total body length which most likely belong to 1-group.)

	Catch Rate	
Year	All	<19cm
1981	0.13	0
1982	0.17	0.01
1983	4.46	0.46
1984	6.97	2.47
1985	32.51	0.77
1986	17.51	0.89
1987	8.32	0.02
1988	6.38	0.97
1989	1.65	0.18
1990	17.81	16.37
1991	48.87	2.11
1992	30.05	0.06
1993	5.8	0.01
1994	3.02	0
1995	1.65	0.10
1996	9.88	5.81
1997	187.24	175.26
1998	7.14	0.21
1999	5.98	0.71
2000	129.23	120.90
2001	329.04	233.76
2002	102.63	9.69
2003	75.25	15.15
2004	124.01	36.74
2005	206.18	90.23
2006	269.2	3.52
2007	80.38	0.16
2008	16.72	0.01
2009	3.74	0
2010	3.19	0.10

Table D2: Stratified mean catch (Kg/haul and Number/haul) and standard error of Blue Whiting in bottom trawl surveys in Spanish waters (Divisions VIIIc and IXa north). All surveys in September-October.

Kg/haul	30-100 m		101-200 m		201-500 m		TOTAL 30-500 m	
Year	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1985	9.50	5.87	119.75	45.99	68.18	13.79	92.83	28.24
1986	9.74	7.13	45.41	12.37	29.54	8.70	36.93	7.95
1987	-	-	-	-	-	-	-	-
1988	2.90	2.59	154.12	38.69	183.07	141.94	143.30	45.84
1989	14.17	12.03	76.92	17.08	18.79	6.23	59.00	11.68
1990	6.25	3.29	52.54	9.00	18.80	4.99	43.60	6.60
1991	64.59	34.65	126.41	26.06	46.07	18.99	97.10	17.16
1992	6.37	2.59	44.12	6.64	29.50	6.16	34.60	4.23
1993	1.06	0.63	14.07	3.73	51.08	22.02	22.59	6.44
1994	8.04	5.28	37.18	8.45	25.42	5.27	29.70	5.19
1995	19.97	13.87	36.43	4.82	15.97	4.10	28.52	3.66
1996	7.27	3.95	49.23	7.19	92.54	17.76	54.52	6.36
Kg/haul	70-120 m		121-200 m		201-500 m		TOTAL 70-500 m	
Year	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1997	17.87	7.35	44.68	10.52	57.14	16.60	42.62	7.29
1998	14.13	4.17	42.78	8.13	78.88	22.01	47.14	7.58
1999	93.01	14.60	112.39	19.92	169.21	50.26	124.66	17.85
2000	62.39	12.00	91.99	14.75	58.72	24.94	76.19	10.61
2001	8.35	3.31	50.18	10.09	52.41	16.71	42.02	7.02
2002	31.40	5.02	69.00	13.41	36.75	12.07	51.80	7.64
2003	42.52	12.22	71.40	11.01	46.43	11.42	58.13	6.92
2004	2.80	2.11	14.05	7.79	59.51	21.41	24.76	7.31
2005	50.63	16.15	95.17	19.28	40.06	8.88	69.94	10.57
2006	14.28	7.01	70.79	12.60	115.08	39.88	71.64	13.18
2007	4.76	3.75	39.10	23.21	21.69	4.41	26.86	11.74

Table D3 Stratified mean catch (Kg/haul) and standard error of bottom trawl surveys in Portuguese waters (Division IXa).

		20-100 m		100-200 m		200-500 m		500-750 m		TOTAL	
Year	Month	y	sy	y	sy	y	sy	y	sy	y	sy
1990	July	**2**	2	**153**	103	**242**	42	**50**	5	**96**	35
	October	**11**	5	**90**	28	**762**	234	**42**	10	**153**	35
1991	July	**1**	1	**140**	40	**268**	38	**64**	18	**98**	15
	October	**8**	5	**83**	18	**259**	53	**121**	27	**91**	11
1992	February	**7**	7	**43**	35	**249**	21	**73**	3	**68**	12
	July	**1**	1	**29**	18	**216**	43	**27**	5	**47**	9
	October	**1**	1	**22**	7	**208**	44	**80**	3	**54**	7
1993	February	**0**	0	**19**	14	**105**	31	**36**	0	**42**	10
	July	**0**	0	**3**	3	**151**	28	**55**	5	**34**	4
	November	**0**	0	**90**	0	**189**	43	**6**	1	**86**	9
1994	October	**0**	0	**374**	30	**283**	32	**49**	7	**174**	11
1995	July	**0**	0	**18**	14	**130**	20	**52**	3	**35**	5
	October	**18**	15	**103**	21	**328**	91	**31**	12	**94**	16
1996	October	**25**	24	**12**	2	**36**	6	**25**	7	**22**	8
1997	June	**0**	0	**3**	3	**116**	42	**45**	12	**27**	7
	October	**2**	1	**54**	20	**77**	13	**7**	2	**32**	8
1998	July	**0**	0	**8**	5	**105**	17	**38**	3	**25**	3
	October	**1**	1	**384**	87	**427**	101	**20**	2	**212**	36
1999	July	**1**	0	**60**	21	**66**	19	**25**	2	**37**	9
	October	**0**	0	**69**	16	**80**	20	**18**	8	**41**	7
2000	July	**23**	13	**109**	34	**116**	10	**63**	6	**75**	13
	October	**11**	4	**155**	53	**196**	22	**54**	4	**99**	19
2001	July	**18**	7	**238**	37	**305**	116	**57**	14	**152**	23
	October	**106**	6	**474**	224	**294**	66		0	**295**	97
2002	October	**19**	12	**176**	81	**180**	24		0	**116**	34
2003	October	**24**	10	**114**	14	**119**	30	**34**	6	**76**	8
2004	October	**0**	0	**44**	10	**380**	27			**84**	15
2005	October	**0**	0	**25**	7	**407**	239			**81**	42
2006	October	**1**	1	**154**	59	**196**	32			**95**	26
2007	October	**1**	1	**136**	66	**141**	25			**91**	32

Table D4: Age stratified CPUE from the Spanish surveys

Numbers	age							
	1	2	3	4	5	6	7	total
1982								
1983		7196	16392	9311	7476	6326	1718	48419
1984		13710	27286	14845	4836	1755	1750	64182
1985		14573	23823	14126	6256	1232	217	60227
1986		3721	14131	14745	7113	1278	505	41493
1987		25328	13153	6664	2938	1029	166	49278
1988		7778	21473	18436	6391	1300	781	56159
1989		15272	18486	17160	8374	3760	1003	64055
1990		21444	19407	5194	1803	1357	451	49656
1991		15924	15370	4989	2329	1045	440	40097
1992		10007	24235	9671	4316	1194	462	49885
1993		4036	13991	22493	7979	1354	658	50511
1994		543	6066	15917	7474	2990	1055	34045
1995		9090	14409	6833	4551	1990	623	37496
1996		3905	14557	14449	3931	3639	1834	42315
1997		8742	15875	11134	3698	1046	450	40945
1998		5884	13236	9803	10844	5229	1153	46149
1999		2048	10268	20242	9833	6287	3047	51725
2000		6207	15518	13987	5375	1264	1414	43765
2001		16223	16488	6830	1620	1148	162	42471
2002		10520	13725	10265	3385	336	69	38300
2003		9069	10461	6517	3983	1932	737	32699

Table D5. Stratified total numbers of blue whiting in French bottom trawl survey. NA no survey.

Year	Bay of Biscay	Celtic Sea	Variance (Biscay)	Variance (Celtic Sea)
1987	1313935981.7	NA	36528215960600000	NA
1988	1232403510.386	NA	104181056815335824	NA
1989	386898631.53	NA	10803455685233600	NA
1990	939550666.3	NA	28702880627300000	NA
1991	252039532.47	NA	3035806271405160	NA
1992	588546250.7	NA	9508732598060000	NA
1994	5518146422	NA	4.069619255e+17	NA
1995	2198718815.9	NA	87909759110826000	NA
1997	2085015191.84	7563919067.5	223112995134135808	326964129692377024
1998	2429940410	847781802.11	2.69773734417e+17	10432317514100000
1999	5332275585.6	4400073060	583976280075900032	8.491756792e+17
2000	3961897973	2945777150	2.8070907774e+17	1.0197334661e+17
2001	1315527385.4	1057830493.98	26628615465300000	30077478942323000
2002	3047994204.6	3656904157.62	208792419841729984	171254737153962912
2003	1308226336.15	1420863842.72	45621762165804800	13006693795190300
2004	1745829772.682	1120840204.85	187350873468851904	285938881215680000
2005	751195629.6	708676111.01	21756850596703000	15983137256765540
2006	7653085198.4	2768183161.2	1027720375481849984	465222574238270016
2007	2921175740.7	1235860328	62665823860790000	71468526200790000
2008	30957020.3	774364861.67	158326076200000	221764902757548992
2009	8332657852.96	9042511712.72	857103189073946496	2457647244348636160
2010	3323790245.4	2078662996.81	160121742822700000	134645834507700000

Table D6. Stratified mean numbers per haul of blue whiting in Irish bottom trawl survey (18 cm cutoff to determine age 0).

Year	Mean number per haul	SE_
2005	1653	659
2006	3143.8	1463.3
2007	941.5	225.4
2008	1225.7	269.5
2009	5698.2	976.6
2010	1415	394.7

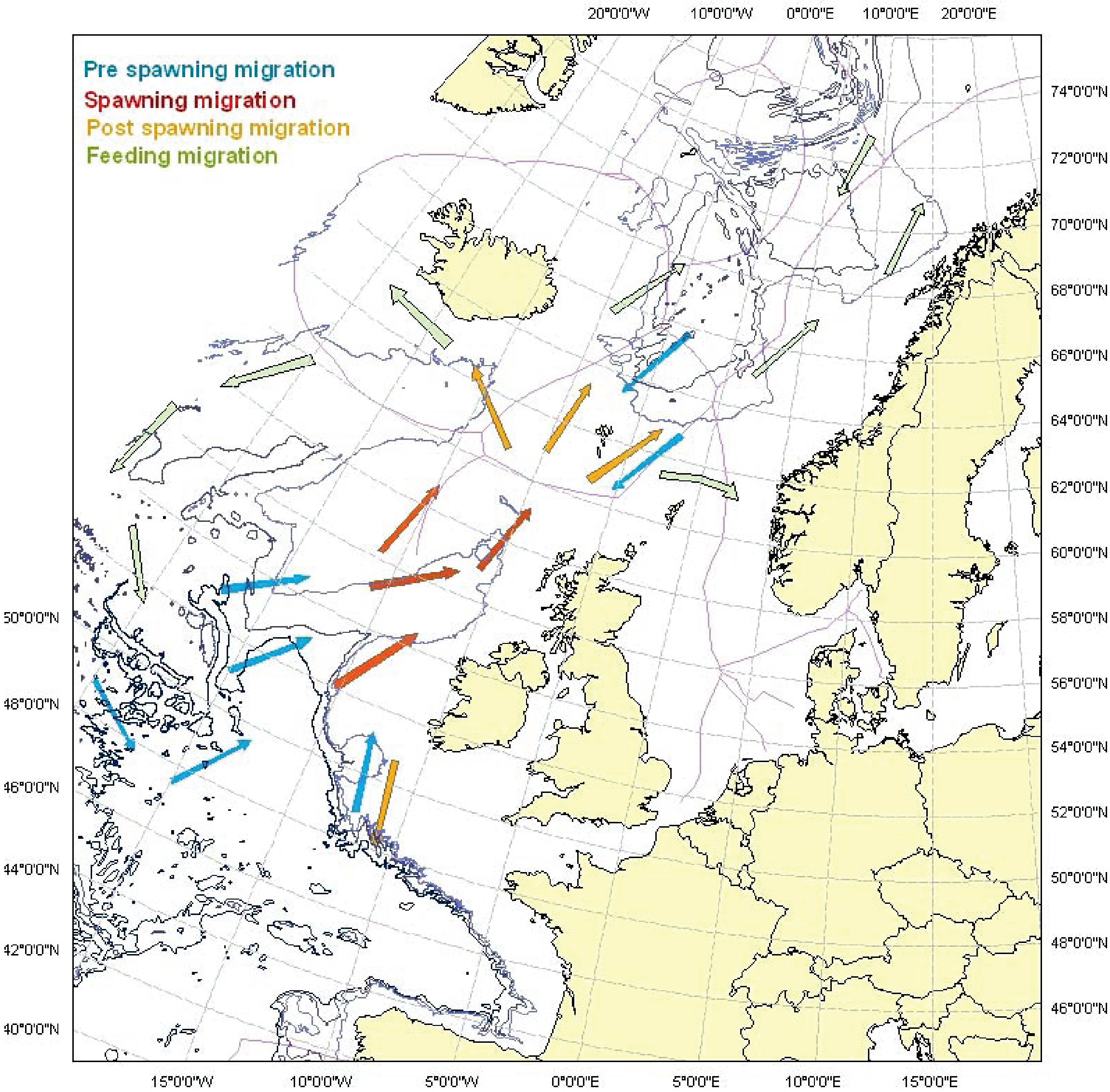

Figure D1. Migration routes for the blue whiting in the Northern Atlantic. Tangen and Sveinbjörnsson (Source: Worsoe Clausen, *et al* 2005)

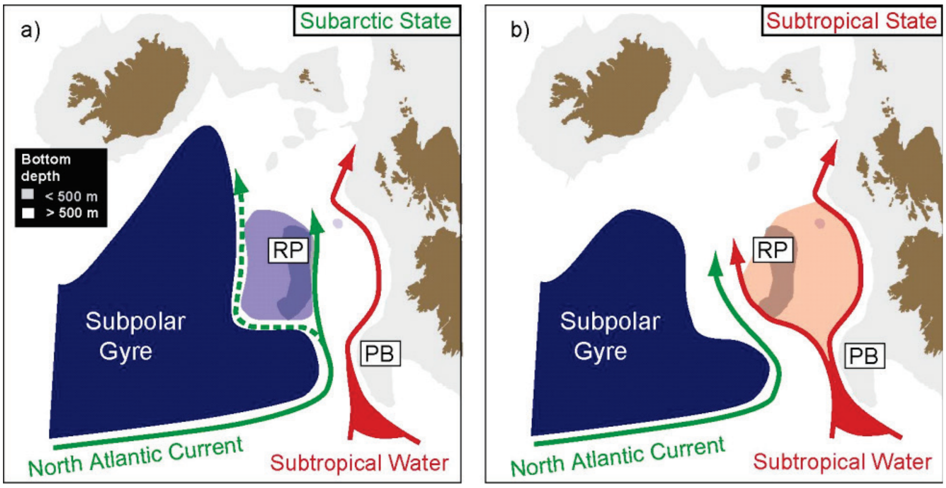

Figure D2: Outline of the source flows to the blue whiting spawning grounds in the Rockall Region. (a) A strong subpolar gyre (SPG) results in strong influence of cold subarctic water near the Rockall Plateau. (b) A weak gyre results in warm subtropical dominance near the plateau (based on Hátún *et al.* 2005). Abbreviations - RP: Rockall Plateau and PB: Porcupine Bank (Source: Hatun *et al.* 2009a).

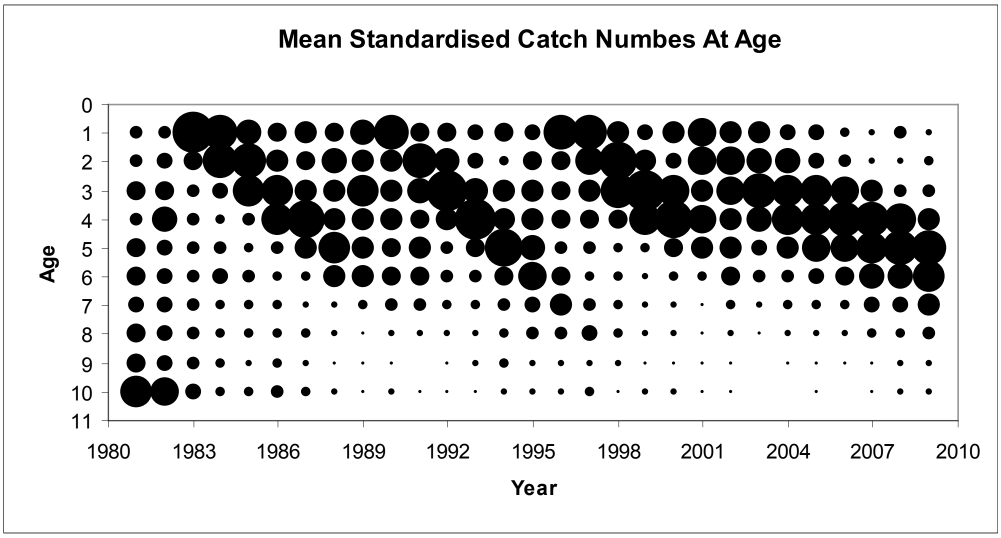

Figure D3: Catch numbers at age mean standardised by year 1981 - 2009

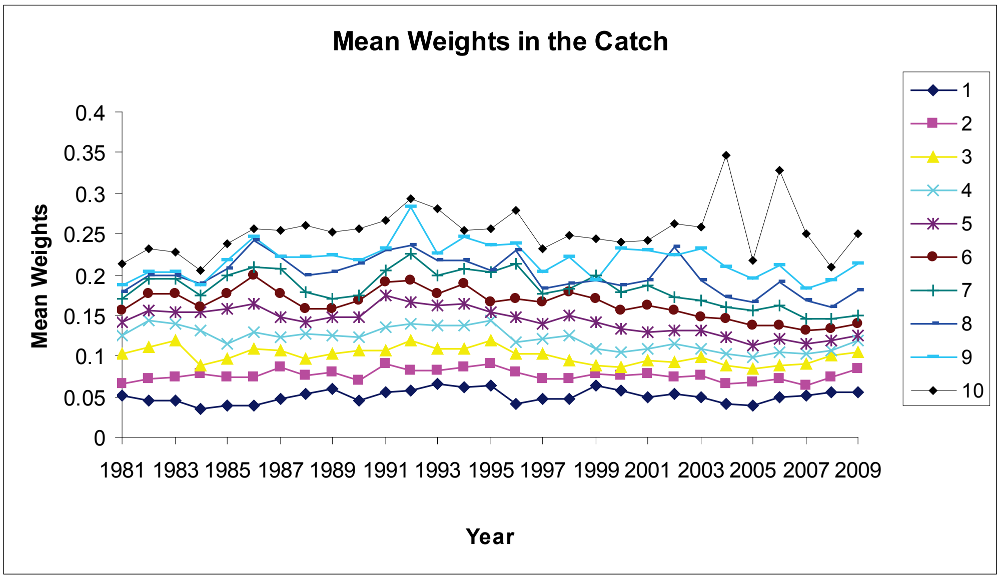

Figure D4: Mean weight in the catch 1981-2009

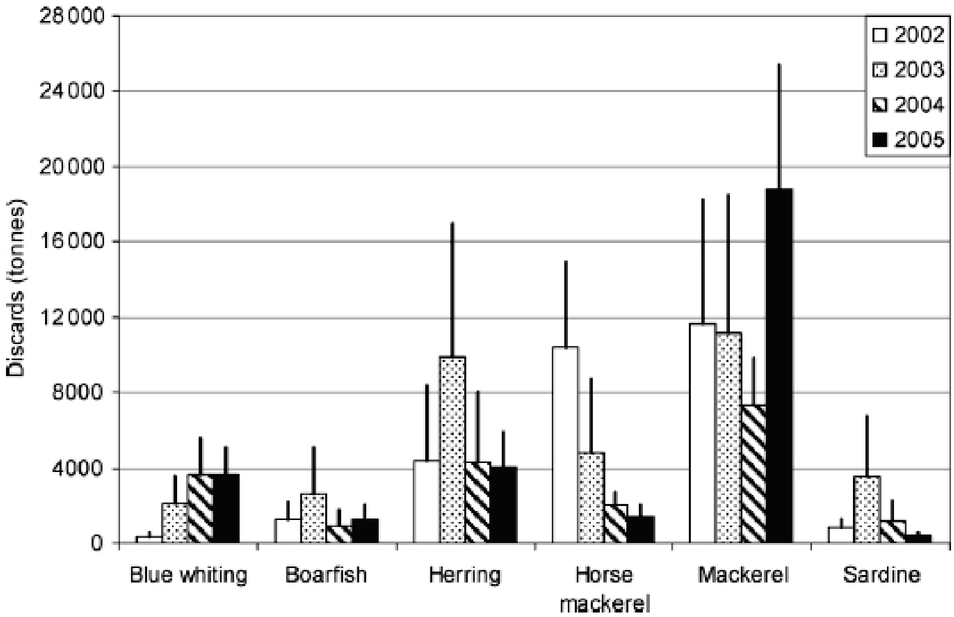

Figure D5: Biomass discarded by the Dutch freezer trawler fleet annually (raised using total number of trips) for the six most discarded species. The vertical lines represent the standard error on the estimates. (From Borges *et al* 2008)

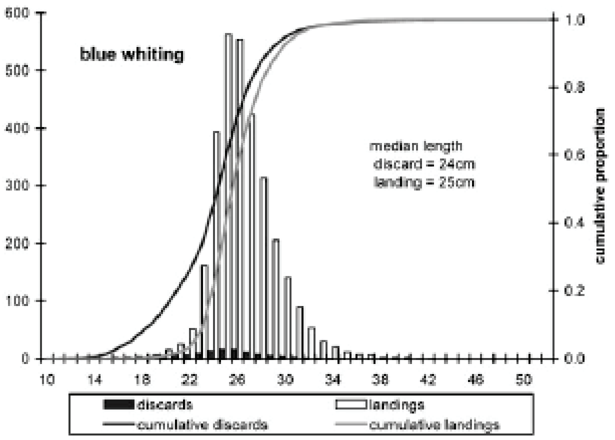

Figure D6: Length frequencies of discarded (filled histograms) and landed blue whiting (white histograms) by the Dutch fleet between 2002 and 2005. (From Borges, *et al* 2008)

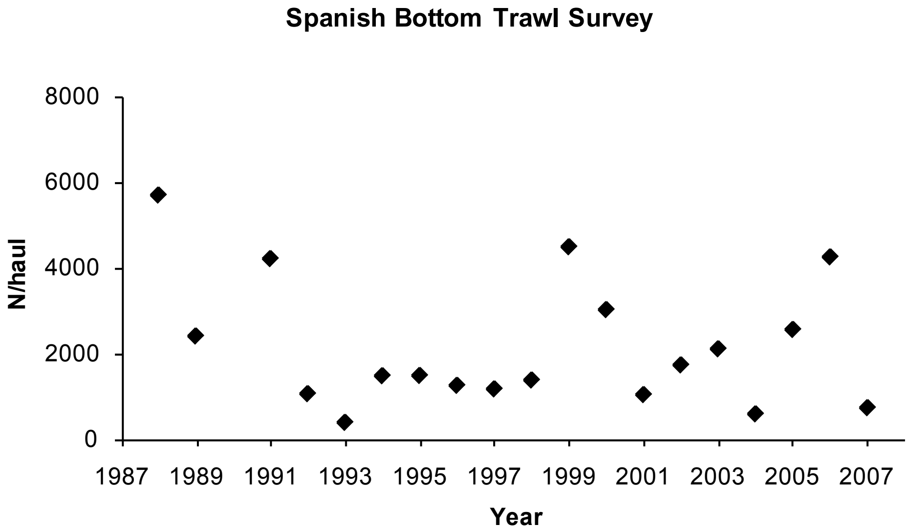

Figure D7. Mean catch rates (Kg/haul and Number/haul) of blue whiting in Spanish bottom trawl survey.

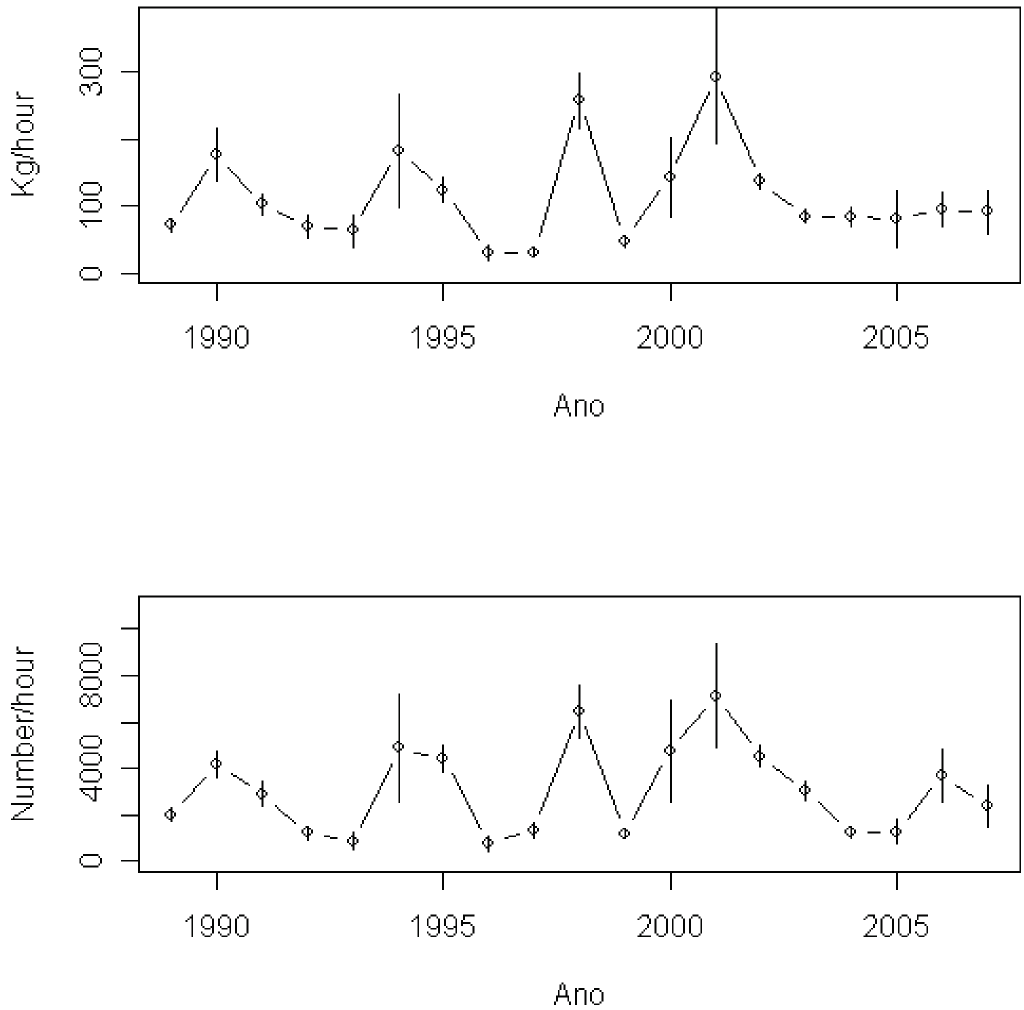

Figure D8: Stratified mean catch (Kg/haul and Number/haul) and standard error of blue whiting in bottom trawl surveys in Spanish waters (Divisions VIIIc and IXa north). All surveys in September –October

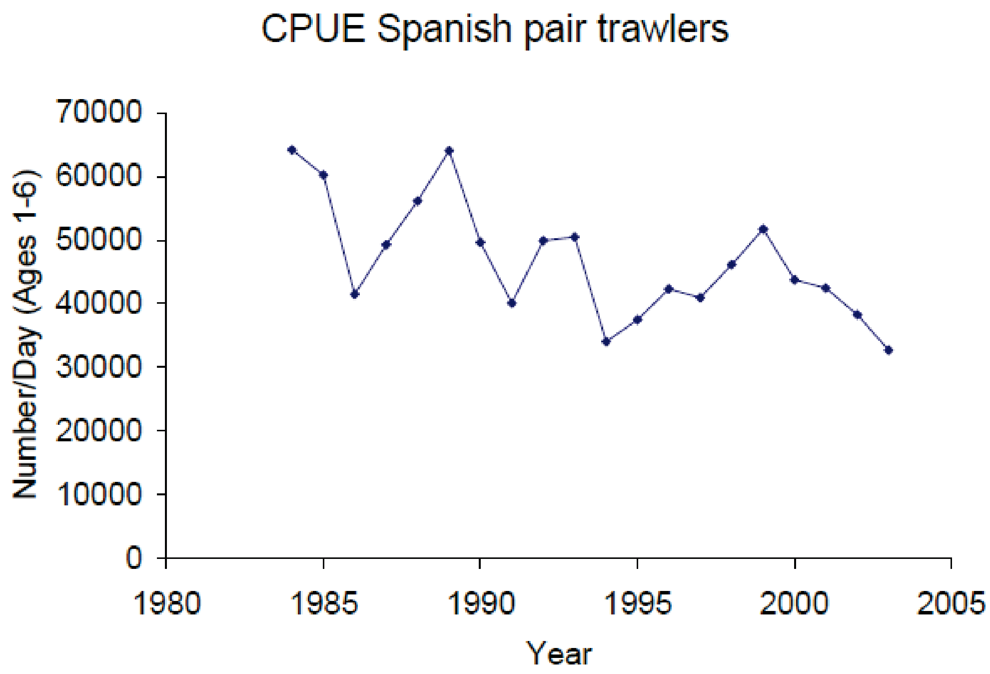

Figure D9: Blue Whiting CPUE from Spanish Pair Trawlers in ICES Div VIIIc and IXa (North)

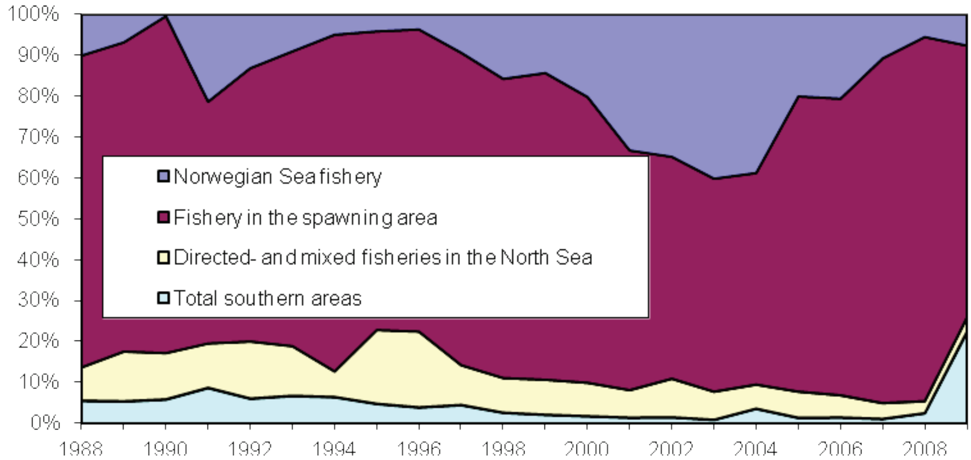

Figure D10: Development of Blue Whiting fisheries in different areas

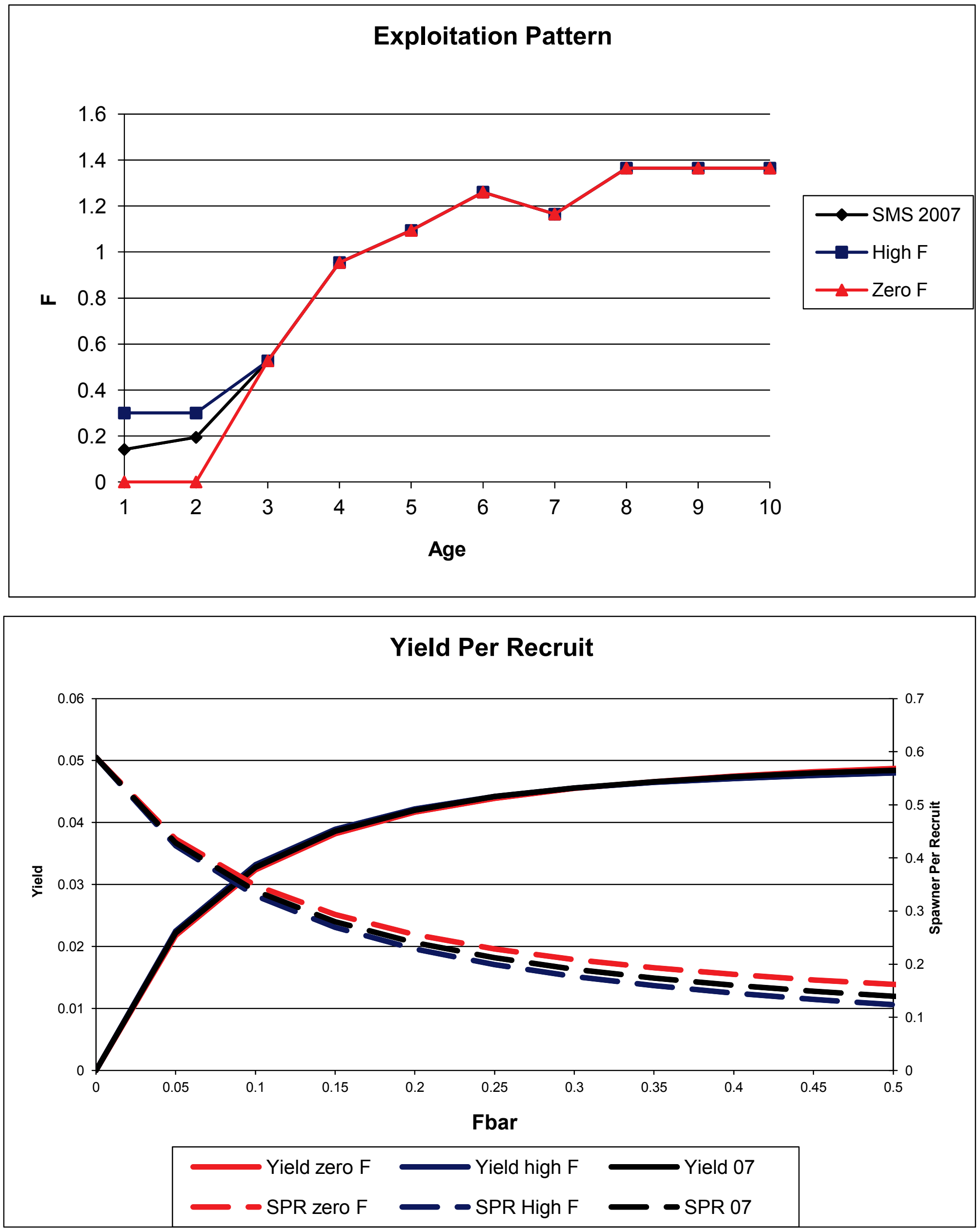

Figure D11: Blue Whiting exploitation pattern (upper) and yield per recruit curves (lower)

Stock Annex 2E – Northeast Atlantic Boarfish

Stock specific documentation of standard assessment procedures used by IC-ES.

Stock:	Boarfish in Sub areas V, IV, VI, VII, VII
Working Group:	WGWIDE 2012
Date:	27th August 2013
Revised by:	WGWIDE/Cormac Nolan & Edward Farrell

A. General

A.1. Stock definition

The boarfish (*Capros aper*, Linnaeus) is a deep bodied, laterally compressed, pelagic shoaling species distributed from Norway to Senegal, including the Mediterranean, Azores, Canaries, Madeira and Great Meteor Seamount (Blanchard and Vandermeirsch, 2005). An analysis of IBTS data suggests a continuity of distribution spanning Subareas IV, VI, VII and VIII (Figure A.1.1). Isolated small occurrences appear in the North Sea in some years and an isolated landing in area Vb2 indicates spill-over into these areas (Figure A.1.2). A hiatus in distribution is apparent between Divisions VIIIc and IXa south. Boarfish are considered very rare in northern Portuguese waters but are abundant further south (Cardador and Chaves, 2010). Based on these results, a single stock is considered to exist in Subareas IV, V, VI, VII and VIII. This distribution is broader than the current EC TAC area: VI, VII, and VIII.

A.2. Fishery

Previous to the development of the fishery, boarfish was a discarded bycatch in pelagic fisheries for mackerel in Subareas VII and VIII. A study by Borges *et al*. (2008) found that boarfish may account for as much as 5% of the total catch of Dutch pelagic freezer trawlers.

The first targeting of boarfish began in 2001. Landings fluctuated between 100 and 700 t per year (Table A.2.1). In 2006 the landings began to increase considerably, and cumulative landings since 2001 are now in excess of 295 000 t. The expansion of the fishery in the mid 2000s was associated with developments in the pumping technology for boarfish catches. These changes made it easier to pump boarfish ashore. The fishery targets dense shoals of boarfish. Catches are generally free from bycatch from September to February. From March onwards a bycatch of mackerel is found in the catches. Information on the bycatch of other species in the boarfish fishery is sparse, though thought to be minimal. The fishery uses typical pelagic trawl nets with mesh sizes ranging from of 32 to 54 mm. Preliminary information suggests that only the smallest boarfish escape this gear. To date only RSW trawlers have participated in the fishery. From 2001 to 2006 only Ireland participated in the fishery. In 2007 UK-Scotland also participated, landing less than 1 000 t. In all years the vast majority of catches have come from SubareaVIIj (Figure A.1.2 and Table A.2.2). In 2010, 137 503 t were caught. Ireland continued to be the main participant (88 456 t), with Denmark taking 39 805 t and Scotland, 9 241 t.

A notional TAC was set for this species for the first time in 2011, covering ICES Subareas VI, VII and VIII. This TAC was set at 33 000 t. Before 2010, the fishery was unregulated. In October 2010, the European Commission notified national authorities that under the terms of Annex 1 of Regulation 850/1998, industrial fisheries for this species should not proceed with mesh sizes of less than 100 mm. In 2011, the European Parliament voted to change Regulation 850/1998 to allow fishing using mesh sizes ranging from 32 to 54 mm.

In 2011, 31 295 t were caught. Ireland continued to be the main participant (20 685 t), with Denmark taking 7 797 t and Scotland 2 813 t. Due to the 2010 net regulation and extended negotiations over quota allocations the Irish target fishery commenced in late Q3 and as such landings in Q1 and Q2 may be considered as bycatch. Twenty-nine Irish registered fishing vessels reported landings of boarfish. Only 2 Scottish vessels reported landings of boarfish, which were in Q3 and Q4. The number of Danish vessels participating in the fishery is unknown.

For 2012, ICES advised that catches of boarfish should not increase, based on precautionary considerations. As supporting information, ICES noted that it would be cautious that landings did not increase above 82 000 t, the average over the period 2008-2010, during which the stock did not appear to be overexploited. In 2012 the TAC was set at 82 000 t by the Council of the European Union.

In August 2012 the executive committee of the Pelagic RAC approved a long term management plan for boarfish. The management plan has not yet been evaluated by ICES.

A.3. Ecosystem aspects

The ecological role and significance of boarfish in the NE Atlantic is largely unknown. However, in the south-east North Atlantic, in Portuguese waters, they are considered to have an important position in the marine food web (Lopes *et al.*, 2006). The diet has been investigated in the eastern Mediterranean, Portuguese waters and at Great Meteor Seamount and consists primarily of copepods, specifically *Calanus helgolandicus*, with some mysid shrimp and euphausiids (MacPherson, 1979; Fock *et al.*, 2002; Lopes *et al.*, 2006). This contrasted with the morphologically similar species, the slender snipefish, *Macroramphosus gracilis* and the longspine snipefish, *M. scolopax*, whose diet comprised *Temora* spp., copepods and mysid shrimps, respectively (Lopes *et al.*, 2006). Despite the obvious potential for these species to feed on fish eggs and larvae, there was no evidence to support this conclusion in Portuguese waters and they were not considered predators of commercial fishes and thus their increase in abundance was unlikely to affect recruitment of commercial fish species (Lopes *et al.*, 2006). If the NE Atlantic population of boarfish is sufficiently large then there exists the possibility of competition for food with other widely distributed planktivorous species.

Both seasonal and diurnal variations were observed in the diet of boarfish in all three regions. In the eastern Mediterranean and Portuguese waters, mysids become an important component of the diet in autumn, which correlates with their increased abundance in these regions at this time (MacPherson, 1979; Lopes *et al.*, 2006). Fock *et al.* (2002) found that boarfish at Great Meteor Seamount fed mainly on copepods and euphausiids diurnally and on decapods nocturnally, indicating habitat dependent resource utilisation.

Boarfish appear an unlikely target of predation given their array of strong dorsal and anal fin spines and covering of ctenoid scales. However, there is evidence to suggest that they may be an important component of some species' diets. Most studies have focused in the Azores and few have mentioned the NE Atlantic, probably due to the relatively low abundance in the region until recent years. In the Azores, boarfish was found to be one of the most important prey items for tope (*Galeorhinus galeus*), thornback ray (*Raja clavata*), conger eel (*Conger conger*), forkbeard (*Phycis phycis*), bigeye tuna (*Thunnus obesus*), yellowmouth barracuda (*Sphyraena viridensis*), swordfish (*Xiphias gladius*), blackspot seabream (*Pagellus bogaraveo)*, axillary seabream (*Pagellus acarne*) and blacktail comber (*Serranus atricauda*) (Clarke *et al*., 1995; Morato *et al*., 1999; Morato *et al*., 2000; Morato *et al*., 2001; Barreiros *et al*., 2002; Morato *et al*., 2003; Arrizabalaga *et al*., 2008). Many of these species also occur in the NE Atlantic shelf waters although it is unknown whether boarfish represent a significant component of the diet in this region.

In the NE Atlantic boarfish have not previously been recorded in the diets of tope or thornback ray (Holden and Tucker, 1974; Ellis *et al*., 1996,). However, this does not prove that they are currently not a prey item. A study of conger eel diet in Irish waters from 1998-1999 failed to find boarfish in the diet (O'Sullivan *et al*., 2004). However, in Portuguese waters a recent study has found boarfish to be the most numerous species in the diet of conger eels (Xavier *et al*., 2010). It has been suggested that boarfish are an important component of the diet of hake (*Merluccius merluccius*), as they are sometimes caught together. However, a recent study of the diet of hake in the Celtic Sea and Bay of Biscay did not report any boarfish in the stomachs of hake caught during the 2001 EVHOE survey (Mahe *et al*., 2007).

The conspicuous presence of boarfish in the diet of so many fish species in the Azores is perhaps more related to the lack of other available food sources than to the palatability of boarfish themselves. Given the large abundance in NE Atlantic shelf waters it is likely that they would have been recorded more frequently if they were a significant and important prey item.

Boarfish are also an important component of the diet a number of sea birds in the Azores, most notably the common tern (*Sterna hirundo*) and Cory's shearwater (*Calonectris diomedea*) (Granadeiro *et al*., 1998; Granadeiro *et al*., 2002). This is surprising given that in the Mediterranean discarded boarfish were rejected by seabirds whereas in the Azores they were actively preyed on (Oro and Ruiz, 1997). Cory's shearwaters are capable of diving up to 15 m whilst the common tern is a plunge-diver and may only reach 2-3 m. It is therefore surprising that boarfish are such a significant component of their diet given that it is generally considered a deeper water fish. In the Azores boarfish shoals are sometimes driven to the surface by horse mackerel and barracuda where they are also attacked by diving sea birds (J. Hart, CW Azores, pers. comm.). Anecdotal reports from the Irish fishery indicate that boarfish are rarely found in waters shallower than 40 m. This may suggest that they are outside the range of shearwaters and gannets, the latter having a mean diving depth of 19.7±7.5 m (Brierley and Fernandes, 2001). However, the upper depth range of boarfish is within maximum diving depth recorded for auks (50 m) as recorded by Barrett and Furness (1990). Given their frequency in the diets of marine and bird life in the Azores, boarfish appear to be an important component of the marine ecosystem in that region. There is currently insufficient evidence to draw similar conclusions in the NE Atlantic.

The length-frequency distribution of boarfish may be important to consider. IBTS data shows an increase in mean total length with latitude (Table A.3.1) and perhaps the smaller boarfish in the southern regions are more easily preyed upon. Length-frequency data of boarfish from stomach contents studies of both fish and sea birds in the Azores indicate that the boarfish found are generally < 10 cm (Granadeiro *et al.*, 1998; Granadeiro *et al.*, 2002).

B. Data

B.1. Historical

In the Northeast Atlantic region boarfish have historically been characterised by apparent fluctuations in abundance. A literature review of historical sources suggests peaks in abundance in the following periods:

- 1840s to 1880s
- 1950s
- Mid 1980s to 1990s

From the 1840s to 1880s large abundances were periodically observed in the western English Channel (Day, 1880-1884; Couch, 1844; Cunningham, 1888). Gatcombe, writing in 1879, stated that they had become an extreme nuisance in trawl fisheries. In the early 1900s boarfish were noted for their sporadic occurrence in the English Channel and were scarce or absent for many years in the area around Plymouth where they had previously been abundant (Cooper, 1952). In the mid 1900s there was another apparent increase in abundance, which Cooper (1952) hypothesised was caused by a 'submarine eagre' that swept shoals of boarfish from submarine canyons in the southern edge of the Celtic Sea onto the continental shelf. It should be noted that these apparent peaks in abundance occurred during periods when fisheries and sampling were less widespread that the present day. The primary distribution area of boarfish, along the shelf edge, was rarely, if ever sampled during this time. Therefore, the observations of peaks in abundance are only related to inshore areas. There is no evidence that boarfish were not also abundant offshore throughout these periods.

Increases in abundance were observed in the Bay of Biscay, Galician continental shelf waters and the Celtic Sea between the 1980s and 2000 (Farina *et al.*, 1997; Pinnegar *et al.,* 2002; Blanchard and Vandermeirsch, 2005). The relative abundance in the Bay of Biscay increased from 0.3% in 1973 to 16% in 2000 resulting in boarfish becoming one of the dominant species in the fish community in this region (Blanchard and Vandermeirsch, 2005).

B.2. Commercial catch

For 2011, catch number-at-age were prepared for Irish, Danish and Scottish landings using the ALKs in table B.2.1. There were a number of unsampled metiers and allocations were made according to table B.2.2. In total 27 samples were collected (16 by Denmark and 11 by Ireland), 4 066 fish were measured for length frequency and 704 fish were aged for construction of the ALKs (Table B.2.3).

For years prior to 2011, a proxy catch-at-age matrix was constructed using the age-length key from a combination of fisheries-independent and dependent data (Table B.2.4). Length-frequencies of commercial catches are available from 2007 onwards (Table B.2.5). Ageing is based on the method that has been validated for ages 0-7 by Hüssy *et al*. (2012; in press). These age samples were collected mainly during 2010. The age range is similar to the published growth information presented by White *et al*. (2011).

ALKs were applied to commercial length-frequency data available for the years 2007-2011 to produce a proxy catch numbers-at-age (Figure B2.1 and Table B.2.6). It can be seen that many older fish are still present in catches, though there appears to be a reduction of older ages since 2007. The modal age in all four years is 6. Other dominant age classes ranged from 4 to 8.

B.3. Biological data

The boarfish are classified in the order Perciformes. They are a small (max 23cm TL), thin, laterally compressed pelagic shoaling species. They have a red to orange colour and are sexually dimorphic. They are widely distributed at depths from the surface to 600m.

Kaya and Özaydin (1995) conducted a study on boarfish in the Mediterranean (Turkish waters) and estimated a maximum age of 4 years and age at maturity 2 years. These results conflicted with the results of White et *al.*, (2011) who attained a maximum age of 26 years and age at maturity of 5.25 and 4.6 years for males and females respectively, based on samples from the NE Atlantic. Neither study included a validation of the ageing method used or information on methods used for maturity determination.

In 2010, a biological study of boarfish commenced based on both fishery dependent and independent samples (n=3376). Samples were collected from ICES Divisions VIa, VIIb, VIIh, VIIj and VIIIa from September 2009 to December 2010 (excluding August). TL ranged from 26 to 180 mm, with one additional fish reaching 233mm. Based on 232 of these samples Hüssy *et al*. (2012) carried out an age validation study. Subsequently an ALK was produced and used for preliminary growth investigations. Farrell *et al*. (2012) also investigated the reproductive biology of the species based on 2015 of these samples. From these 2 studies the following biological background information has been gathered:

Boarfish reach a maximum age of 31 years. An ALK based on 407 age readings, from 0 to 28 years, of males and females combined was applied to a combination of length-only fishery independent and dependant data (n=1633). The von Bertalanffy growth curve was constructed based on the typical parameterisation of the von Bertalanffy growth equation (Table B.3.1 and Figure B.3.1):

$TL_{age} = L_{inf}*(1-exp(-K*(age-t0)))$

The growth curve and ALK were used to investigate length-at-age, age distribution and maturity at age/length. Growth is fastest in the first 2-3 years then levels off and energy is allocated to other processes such as reproduction. The age distribution (Figure B.3.2) is uni-modal with a peak at 7 years (corresponding to approx. 12cm). Length classes were continuous up to 18cm after which only one individual fish was present in the 23cm length class. The abundance of females peaked in the 12cm length class, while the highest number of males was observed in the 11cm length class.

The length and age at 50 % maturity were 9.7 cm TL and 3.5 years, respectively (Figure B.3.3). The reproductive cycle commenced between February and April and finished between October and December, when fish entered the resting phase. Oocyte development was asynchronous and all oocytes stages were present concurrently in spawning fish. There was no hiatus between pre-vitellogenic and vitellogenic oocytes. Spawning occurred in June and July with a notable peak in July (Figure B.3.4). No samples were available from August. The boarfish is a batch spawner. In September there was a generalised atresia and remaining oocytes were observed to be resorbed. Aquarium observations of spawning fish indicated that males spawned daily whilst females spawned every 2-3 days. In the controlled aquarium environment spawning lasted approximately 9 months. All indications are that the boarfish has indeterminate fecundity.

B.4. Surveys

B.4.1. IBTS

The western IBTS data and CEFAS English Celtic Sea Groundfish Survey were investigated for their utility as abundance indices. An index of abundance was constructed from the following surveys:

- EVHOE, French Celtic Sea and Biscay Survey, (Q4) 1997 to 2011
- IGFS, Irish Groundfish Survey, (Q4) 2003 to 2011
- WCSGFS, West of Scotland, (Q1 and Q4) 1986 to 2011 (no Q4 survey in 2010)
- SPPGFS, Spanish Porcupine Bank Survey, (Q3) 2001 to 2011
- SPNGFS, Spanish North Coast Survey, (Q3/Q4) 1991 to 2011
- ECSGFS, CEFAS English Celtic Sea Groundfish Survey, (Q4) 1982 to 2003

From the IBTS data CPUE was computed as the number of boarfish per 30 minute haul. The abundance of boarfish per year per ICES Rectangle was then calculated by summing the boarfish in a given rectangle and dividing by the total number of hauls in that rectangle. Length frequencies are presented in Table B.4.1 for each survey. The complete area was sampled from 2003-2011.

The shoaling nature of the species results in occasional large hauls. This is evidenced in the 2008 data which appears to indicate a peak in abundance. Therefore, the number of rectangles sampled was compared with the number of rectangles in which boarfish were caught (Figure B.4.1). The occurrence of boarfish increased from 2003 to 2007 despite a decrease in the number of rectangles sampled from 2004 to 2010. From 2007 to 2010 there was a slight decrease in the occurrence of boarfish but this appears to have levelled off in 2011.

The IBTS appears to give a relative index of abundance, with good resolution between periods of high and low abundance. The main centres of abundance in the survey (Figure A.1) correspond to the main fishing grounds (Figure A.2). Figure B.4.2 shows the signal in abundance, increasing in the 1990s, declining again in the early 2000s, before increasing again. These trends have been reported by (Farina *et al.*, 1997; Pinnegar *et al.*, 2002; Blanchard and Vandermeirsch, 2005). These authors used IBTS and other trawl survey data to show the increased abundance of the species in this area.

B.4.2. Acoustic Survey

In July 2011, a Boarfish Acoustic Survey (BFAS) series was initiated by the Irish Industry. The 2011 survey was conducted aboard the FV ''Felucca'' with a towed body system with a calibrated 38 kHz split beam transducer (O'Donnell *et al.*, 2012a). The survey was designed to extend the MSHAS conducted aboard the RV Celtic Explorer to the south, which increased the range of continuous coverage from approximately 58.5°N to 48.5°N (Figure B.4.2.1). The combined surveys resulted in a continuous coverage over 33 days, 90 000 nmi^2 and transect coverage over 4 500 nmi. 24 trawls were sampled and lengths, weights, maturity data and otoliths of boarfish were collected.

As no species-specific target strength (TS) existed for boarfish, an industry funded project was started to model the TS based on MRI scans of the swim bladders of whole fish taken from the observed size range during the survey. 3D swimbladder dimensions of each fish sample were used as input to a KRM model. An estimated TS-L relationship of -65.98dB was derived based on model calculations (Fässler & O'Donnell, unpublished data). This TS was applied retrospectively to the 2011 BFAS survey data and will be applied to future surveys to develop the time series.

In July 2012 the BFAS series was continued, with the survey being conducted aboard the FV ''Father McKee'' and funded by an Irish quota allocation of 1,400 tonnes (O'Donnell *et al.*, 2012b). The same equipment was used as during the 2011 survey and the survey track was broadly similar (Figure B.4.2.1). In 2012 the survey methodology was further refined by switching to daylight surveying. The daylight sampling protocol has increased the precision of the survey estimate and should be maintained in the future.

The geographical distribution of boarfish between the 2011-2012 surveys shows a similar pattern with the 2 highest abundance areas dominating between years (southern and western areas). In the northernmost area and Porcupine Bank boarfish were observed in small low density clusters. Although important in terms of western and northern stock containment these areas would not be considered core spawning areas for boarfish.

Boarfish behaviour in terms of school positioning in the water column showed geographical differences from north to south. In the western area boarfish schools were exclusively located on shelf and were observed higher in the water column. In the southern area schools located on the shelf edge were closer to the seabed when in comparable water depths. As boarfish are spawning during the survey this behaviour maybe a spawning strategy related to ambient hydrographic conditions encountered for exposed sites on the shelf edge. Size structure of boarfish within trawl catches showed a trend of larger fish further north and a broader length range further south. This size trend is consistent with previous observations from 2011.

C. Assessment: data and method

Assessments, projections and reference points (Sections C to H) from 2011 are presented here. For 2012 assessment see main text.

A number of exploratory assessments for boarfish were carried out in 2011.

Model used: Survey Based Assessment using SURBA (Needle, 2003) (Figure C.1)

Model Options chosen:

Age weightings; Set at 1

Catchabilities: Set at 1

Estimation Type: Relative

Mean F: Ages 6-10

SSQ Lambda: 1

Index rho: 2

No of years for retrospective: 7

Estimation constraints: bounded

Type	Name	Year range	Age range	Variable from year to year Yes/No
West	Weight at age in the stock	1997-2010	1-12	Yes
Matprop	Proportion mature at age	1997-2010	1-12	No
Natmor	Natural mortality	1997-2010	1-12	No

Type	Name	Year range	Age range
Tuning fleet 1	EVHOE survey	1997 - 2010	1-12

Model used: Pseudo Cohort Analysis using VIT

Model Options chosen:

Standard VPA

Single Gear

Terminal F: 0.14

Von Bertalanffy parameters: L_{inf} = 15.563

K = 0.191

t_0 = -1.663

Length Weight parameters: a = 0.0292

b = 2.838

Input data types and characteristics:

Type	Name	Year range	Age range	Variable from year to year Yes/No
Caton	Catch in tonnes	2010	1-20	Yes
Canum	Catch at age in numbers	2010	1-20	Yes
Matprop	Proportion mature at age	2010	1-20	Yes
Natmor	Natural mortality	2010	1-20	Yes

See Tables C1.1 and 1.2.

D. Short-Term Projection

An exploratory short term projection was carried out in 2011.

Method Used: Harvest Ratios where the Harvest Ratio = 1-exp(-F).

Catch options are presented based on a number of SSB and F options.

E. Medium-Term Projections

A yield per recruit analysis was conducted in 2011 (Minto *et al.* WD 2011) and $F_{0.1}$ was estimated to be 0.13 whilst F_{max} was estimated as in the range 0.23 to 0.33. (Figure E.1 and E.2). The estimation of $F_{0.1}$ was considered to be quite good.

F. Long-Term Projections

No long term projections were carried out.

G. Biological Reference Points

F-based reference points are proposed for this stock:

$F_{0.1}$ 0.13

F_{max} 0.23

F_{pa} $F<M = 0.16$

Further work is required to propose precautionary or yield based biomass reference points.

H. Other Issues

H.1 Management and ICES advice

In 2010, an interim management plan was proposed by Ireland for boarfish in ICES Divisions VI, VII and VIII. The plan was as follows:

1) Until a long term management plan has been developed, and evaluated, the following interim TAC setting rule shall apply.

2) The TAC for 2011 (hereinafter referred to as the Reference TAC) shall be set in the range 22,000-33,000 t, 50%-75% of the Recent Average Yield 2007-2009.

3) The TAC for 2012 shall be based on the Reference TAC, adapted by the rule, below, based on the Exploitation Indicator (E) and Reproductive Capacity Indicator (R)*:

a) If the average of either E or R in the past two years is 20% or more lower than in the preceding three years, a 15% TAC decrease applies.

b) If the average of either E or R in the past two years is 20% or more higher than in the preceding three years, a 15% TAC increase applies.

c) If the average of either E or R in the past two years is less than 20% different than in the preceding three years, no TAC change applies.

d) Notwithstanding 3.b above, in no case shall the TAC for a given year exceed the Reference TAC.

1) A precautionary closed season shall operate between the 15th March and the 31st August. This is because it is known that mackerel and boarfish are caught in mixed aggregations at these times.

2) A closed area shall be implemented in VIIg from 1st September to 31st October, in order to prevent catches of Celtic Sea herring, known to form feeding aggregations in this region at these times.

3) If catches of species covered by TAC, other than boarfish amount to more than 5% of the total catch by day by ICES statistical rectangle, then fishing must cease in that rectangle.

4) Vessels participating in the fishery for boarfish shall only land in designated ports.

5) Participating vessels already facilitate scientific studies, and observer coverage, and this cooperation shall be further developed.

***Indicator Definitions**

Exploitation Indicator E is defined as follows:

The mean length of fish of size greater than length at maturity as estimated in 2007 in the ICES western IBTS.

Reproductive Indicator R is defined as follows:

The total abundance of mature boarfish as estimated per year by the ICES western IBTS survey.

In 2011, ICES was asked by the European Commission to provide advice for boarfish in 2012 for the Celtic Sea and in the Bay of Biscay and the Iberian Coast. Data analysis suggests that a single management area exists in Subareas IV, V, VI, VII and VIII. This differs from the request made by the EC to ICES and also differs to the TAC area (VI, VII and VIII).

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Table A.2.1. Boarfish in Subareas V, VI, VII, VIII. Landings by year (t), 2001–2011. (Data provided by Working Group members). These figures may not in all cases correspond to the official statistics and cannot be used for management purposes.

Year	Ireland	Denmark	Scotland	Unallocated	Discards	Total
2001	120	0	0	NA	NA	120
2002	91	0	0	NA	NA	91
2003	458	0	0	NA	10810	11268
2004	675	0	0	NA	4416	5090
2005	165	0	0	NA	5740	5905
2006	2772	0	0	NA	4344	7115
2007	17615	0	772	NA	2640	21027
2008	21585	3098	0.45	NA	9148	33831
2009	68629	15059	0	NA	6305	89993
2010	88457	39805	9241	NA	6459	143962
2011	20685	7797	2813	NA	5642	36937

Table A.2.2 Boarfish in ICES Subareas V, VI, VII, VIII. Landings by year (t), 2001–2011 and area where available. (Data provided by Working Group members). These figures may not in all cases correspond to the official statistics and cannot be used for management purposes.

	Denmark	Ireland	Scotland	Total
2001	0	120	0	120
2002	0	91	0	91
2003	0	458	0	458
VI		65		65
VII		393		393
2004	0	675	0	675
VI		292		292
VII		345		345
VIII		38		38
2005	0	165	0	165
VI		10		10
VII		117		117
VIII		38		38
2006	0	2772	0	2772
VI		21		21
VII		2750		2750
VIII		1		1
2007	0	17615	772	18386
V		6		6
VI		93		93
VII		17510	772	18282
VIII		5		5
2008	3098	21584	0	24683
VI		28	0	28
VII		21557		21557
2009	15059	68629	0	83688
VI		45		45
VII		68584		68584
2010	39805	88457	9241	137503
VI		1355	10	1365
VII	39805	87101	9231	136138
2011	7797	20685	2813	31295
VI		26		26
VII	7779	20659	2813	31251
VIII	18			
Total	**65759**	**221250**	**12826**	**299836**

Table A.3.1 Boarfish in ICES Subareas VI, VII, VIII. IBTS length-frequency data.

		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
IRL	8	1																		
Q4	8.5																			
VIIh	9																			
	9.5	1	5																	
	10		7	3																
	10.5		6	2		2														
	11		1	3	1	4	2	2												
	11.5				2	9	2	2												
	12					5	4	4	2											
	12.5					2	3	2	2	1	3									
	13					3	3		3	2					1			2		1
	13.5						1	1	1	1	2	3	1			1	1	2		1
	14										1	2	2	1	1	1				1
	14.5									1					1			2		1
	15															1		2		1

		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
IRL	9		1																	
Q4	9.5		1																	
VIIj	10		1		2															
	10.5		1				1													
	11			2	2	2	1	1												
	11.5			1	4	15	8	4	2											
	12				1	12	10	8	7	5		1								
	12.5				1	8	12	6	7	6	4	2								
	13					1	4	8	5	6	5	8	2	2	1	1		1	1	
	13.5						2	1	3	5	2	5	5	5	2	1	4	2	1	6
	14								1	2	1	4	6	2	4	3	1	2	2	12
	14.5									1		2	3	5		5	2	2		14
	15										1	1	1	1		5	4	2	1	19
	15.5															2	1	2	1	19
	16																			8
	16.5																			2
	17																			1

IRL & DNK		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
Q4	7	1																		
VIIh	8	1																		
	9	1	5	1																
	10		18	10	5	4														
	11		1	6	12	20	6	5												
	12				1	13	20	13	6	3	4									
	13					4	9	5	6	8	5	3	2	1	5	1	1	4		3
	14								1	1	3	4	4	2	3	2		4	3	9
	15												1	1	1	4	2	3	2	9
	16																			1

IRL & DNK		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
Q4	7	1																		
VIIJ	8		1																	
	9		1																	
	10		2	2	2		1													
	11			3	6	21	14	5	2											
	12				2	25	25	18	16	12	4	3								
	13					2	9	10	11	12	10	13	7	9	3	3	4	3	2	6
	14								1	5	3	8	9	7	5	9	6	6	2	28
	15										1	1	1	2	1	7	5	4	2	38
	16													1	1					11
	17																			1

Table B.2.1. Boarfish age length key produced from 2011 commercial samples. Figures highlighted in grey are estimated.

		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
IRL	8	1																		
Q4	8.5																			
VIIh	9																			
	9.5	1	5																	
	10		7	3																
	10.5		6	2		2														
	11		1	3	1	4	2	2												
	11.5				2	9	2	2												
	12					5	4	4	2											
	12.5					2	3	2	2	1	3									
	13					3	3		3	2					1			2		1
	13.5						1	1	1	1	2	3	1			1	1	2		1
	14										1	2	2	1	1	1				1
	14.5									1					1			2		1
	15															1		2		1

		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
IRL	9		1																	
Q4	9.5		1																	
VIIj	10		1		2															
	10.5		1				1													
	11			2	2	2	1	1												
	11.5			1	4	15	8	4	2											
	12				1	12	10	8	7	5		1								
	12.5				1	8	12	6	7	6	4	2								
	13					1	4	8	5	6	5	8	2	2	1	1		1	1	
	13.5						2	1	3	5	2	5	5	5	2	1	4	2	1	6
	14								1	2	1	4	6	2	4	3	1	2	2	12
	14.5									1		2	3	5		5	2	2		14
	15										1	1	1	1		5	4	2	1	19
	15.5															2	1	2	1	19
	16																			8
	16.5																			2
	17																			1

IRL & DNK		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
Q4	7	1																		
VIIh	8	1																		
	9	1	5	1																
	10		18	10	5	4														
	11		1	6	12	20	6	5												
	12				1	13	20	13	6	3	4									
	13					4	9	5	6	8	5	3	2	1	5	1	1	4		3
	14								1	1	3	4	4	2	3	2		4	3	9
	15												1	1	1	4	2	3	2	9
	16																			1

IRL & DNK		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
Q4	7	1																		
VIIJ	8		1																	
	9		1																	
	10		2	2	2		1													
	11			3	6	21	14	5	2											
	12				2	25	25	18	16	12	4	3								
	13					2	9	10	11	12	10	13	7	9	3	3	4	3	2	6
	14								1	5	3	8	9	7	5	9	6	6	2	28
	15										1	1	1	2	1	7	5	4	2	38
	16													1	1					11
	17																			1

Table B.2.2. Age length key allocations made to unsampled metiers in 2011.

Country	Area	Quarter	Landed (t)	ALK
IRL	VIIb	1	39	IRL_VIIj_Q4
IRL	VIIj	1	38	IRL_VIIj_Q4
IRL	VIIb	2	1	IRL_VIIj_Q4
IRL	VIIh	3	820	IRL_VIIh_Q4
IRL	VIIj	3	1092	IRL_VIIj_Q4
IRL	VIa	4	26	IRL_VIIj_Q4
IRL	VIIb	4	235	IRL_VIIj_Q4
IRL	VIIc	4	9	IRL_VIIj_Q4
IRL	VIIg	4	811	IRL_VIIj_Q4
IRL	VIIh	4	7720	IRL_VIIh_Q4
IRL	VIIj	4	9894	IRL_VIIj_Q4
DNK	VIIh	1	32	Combined IRL&DNK (1.0cm)_VIIh_Q4
DNK	VIIIa	1	18	Combined IRL&DNK (1.0cm)_VIIh_Q4
DNK	VIIj	1	1	Combined IRL&DNK (1.0cm)_VIIj_Q4
DNK	VIIh	4	4123	Combined IRL&DNK (1.0cm)_VIIh_Q4
DNK	VIIj	4	3623	Combined IRL&DNK (1.0cm)_VIIj_Q4
SCT	VIIh	3	434	IRL_VIIh_Q4
SCT	VIIh	4	2379	IRL_VIIh_Q4

Table B.2.3. Boarfish in ICES Subareas V, VI, VII, VIII. Sampling intensity by country of commercial catches.

			DK				IRL				SCT			
Year	Q	Area	Landings	Samples	Measured	Allocated	Landings	Samples	Measured	Allocated	Landings	Samples	Measured	Allocated
2007	1	VIa					12	0	0	VIIj_Q2 and VIa_Q4				
	1	VIIIa					5	0	0	VIIj_Q2 and VIa_Q4				
	1	VIIj					5253	0	0	VIIj_Q2 and VIa_Q4	772	0	0	Irish 2007 combined
	2	VIIg					120	0	0	VIIj_Q2 and VIa_Q4				
	2	VIIj					4130	2	197	VIIj_Q2 and VIa_Q4				
	3	VIIb					0	0	0	VIIj_Q2 and VIa_Q4				
	4	Vb2					6	0	0	VIIj_Q2 and VIa_Q4				
	4	VIa					82	1	20	VIIj_Q2 and VIa_Q4				
	4	VIIb					1259	0	0	VIIj_Q2 and VIa_Q4				
	4	VIIj					6748	0	0	VIIj_Q2 and VIa_Q4				
	Total		0	0	0		17615	3	217		772	0	0	
2008	1	VIa					5	0	0	VIIj_Q4				
	1	VIIg					184	0	0	VIIj_Q4				
	1	VIIj					5041	0	0	VIIj_Q4				
	2	VIIj					46	0	0	VIIj_Q4				
	3	VIIj					4067	0	0	VIIj_Q4				
	4	VIa					23	0	0	VIIj_Q4	0.5	0	0	Irish 2008 combined
	4	VIIb					3	0	0	VIIj_Q4				
	4	VIIj					12216	1	152	VIIj_Q4				
	Total		3098	0	0		21584	1	152		0.5	0	0	
2009	1	VIIb					55	0	0	VIIj_Q3				
	1	VIIg					2979	0	0	VIIj_Q3				
	1	VIIh					1971	0	0	VIIj_Q3				
	1	VIIj					10901	2	359	VIIj_Q3				
	2	VIIg					1933	0	0	VIIj_Q3				
	2	VIIh					3169	0	0	VIIj_Q3				
	2	VIIj					2727	0	0	VIIj_Q3				
	3	VIIh					10378	0	0	VIIj_Q3				
	3	VIIj					11423	1	175					
	4	VIa					45	0	0	VIIj_Q4				
	4	VIIb					18	0	0	VIIj_Q4				
	4	VIIh					2707	0	0	VIIj_Q4				
	4	VIIj					20321	6	941					
	Total		15059	0	0		68629	9	1475		0	0	0	
2010	1	VIa									10	0	0	Irish 2010 VIIb_Q1
	1	VIIb					1069	1	102					
	1	VIIg	577	1	77		2392	0	0	VIIj_Q1				
	1	VIIh	1079	0	0	VIIg+VIIj_Q1	326	1	94					
	1	VIIj	32422	2	193		34466	12	1447		2504	0	0	Irish 2010 VIIj_Q1
	2	VIIh					102	0	0	VIIh_Q3				
	2	VIIj	344	0	0	VIIj_Q1								
	3	VIIg					338	0	0	VIIh_Q3				
	3	VIIh	377	0	0	VIIh_Q4	5540	8	1316		548	0	0	Irish 2010 VIIh_Q3
	3	VIIj	2660	0	0	VIIj_Q4	11531	31	3275		2171	0	0	Irish 2010 VIIj_Q3
	4	VIa					1355	1	117					
	4	VIIb					1189	0	0	VIIj_Q4				
	4	VIIc					35	0	0	VIIj_Q4	4	0	0	Irish 2010 VIIj_Q4
	4	VIIe	2	0	0	VIIh_Q4								
	4	VIIg	94	0	0	VIIh+VIIj_Q4	920	0	0	VIIh_Q4				
	4	VIIh	9	3	384		2484	6	715		1165	0	0	Irish 2010 VIIh_Q4
	4	VIIj	2241	2	217		26710	27	2738		2840	0	0	Irish 2010 VIIj_Q4
	Total		39805	8	871		88457	87	9804		9241	0	0	
2011	1	VIIb					39	0	0	VIIj_Q4				
	1	VIIh	32	0	0	VIIh_Q4								
	1	VIIIa	18	0	0	VIIh_Q4								
	1	VIIj	1	0	0	VIIj_Q4	38	0	0	VIIj_Q4				
	2	VIIb					1	0	0	VIIj_Q4				
	3	VIIh					820	0	0	VIIh_Q4	434	0	0	Irish 2011 VIIh_Q4
	3	VIIj					1092	0	0	VIIj_Q4				
	4	VIa					26	0	0	VIIj_Q4				
	4	VIIb					235	0	0	VIIj_Q4				
	4	VIIc					9	0	0	VIIj_Q4				
	4	VIIg					811	0	0	VIIj_Q4				
	4	VIIh	4123	11	1347		7720	3	319		2379	0	0	Irish 2011 VIIh_Q4
	4	VIIj	3623	5	611		9894	8	1789					
	Total		7797	16	1958		20685	11	2108		2813	0	0	

Table B.2.4. Boarfish in ICES Subareas V, VI, VII, VIII. Age length key produced from combined commercial and survey samples. Shaded portion indicates commercial fishery size and age range.

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	28	29
2.5	3																												
3	10																												
3.5	2																												
4	1																												
5		2																											
5.5		7																											
6		5																											
6.5		6	2																										
7		5	3																										
7.5		4	3																										
8			5	1																									
8.5			17	6																									
9		1	7	9	1																								
9.5			3	11	6																								
10			1	6	17	7	1																						
10.5			1	1	14	10	1																						
11					13	15	7	2																					
11.5				2	2	8	7	4	1																				
12						3	14	3	5																				
12.5					1	2	5	8		4	3	1																	
13							3	3	4	4	2	1	1	1			1												
13.5								3	3	2	3	1	1	2		1	1			1	1								1
14										4	3	1	3		1		1							1	1				
14.5								1		2	2		2	2	3				2		1	2							
15											1				1	1		1	1		1	1	1		1			1	
15.5											1	1	3		1		1			1		1			1		1	1	
16																				1			1	1					
16.5																1			1		1			1		2			
17																		1	1			2	3		2				
17.5																							1						
18																											1		
23																													

Table B.2.5. Boarfish in ICES Subareas V, VI, VII, VIII. Length-frequency distributions of the international catches (raised numbers in '000s) for the years 2007-2011.

TL (cm)	2007	2008	2009	2010	2011	Total
6	0	0	0	156	0	156
6.5	0	0	0	439	0	439
7	0	0	0	1090	522	1090
7.5	0	0	1354	1574	0	2928
8	0	0	677	375	1345	1051
8.5	0	0	0	1082	0	1082
9	0	0	677	5382	851	6059
9.5	0	7473	17367	7883	7012	32722
10	9609	11209	54130	29410	33243	104358
10.5	0	52308	174796	130889	15848	357994
11	84555	63517	343283	361774	70615	853129
11.5	0	59781	321637	655875	93487	1037293
12	44199	119561	297737	739025	189434	1200523
12.5	0	70990	207739	564347	114904	843075
13	82633	52308	147965	353484	133539	636390
13.5	0	29890	149314	246146	51235	425350
14	117224	22418	105782	224611	50857	470036
14.5	0	14945	71273	127711	25309	213929
15	65338	33627	47816	125463	25569	272243
15.5	0	11209	13082	81386	5473	105678
16	13452	11209	19397	24256	4181	68314
16.5	0	3736	4061	6209	2280	14006
17	0	3736	677	1913	456	6326
17.5	0	0	0	0	0	0
18	0	0	0	283	0	283

Table B.2.6. Boarfish in ICES Subareas V, VI, VII, VIII. Proxy catch numbers-at-age of the international catches (raised numbers in '000s) for the years 2007-2011.

	2007	2008	2009	2010	2011
1	0	0	1032	2414	0
2	343	4853	13009	11225	2894
3	2060	18696	57001	72678	41886
4	39812	93367	297595	294261	28107
5	47670	124962	404890	567428	30014
6	61117	172752	441056	877869	175247
7	25467	92002	249530	522388	143491
8	29009	58872	138814	293537	106776
9	54648	47012	127265	276489	77553
10	43733	41471	107731	231973	59726
11	13662	13521	34811	78538	45925
12	31536	18729	51641	114532	40229
13	4725	10483	33294	59892	24207
14	16409	12001	27261	59026	19596
15	7472	7802	13940	26993	16624
16	13662	9310	25101	53864	19508
17	7472	5379	5136	13263	13530
18	7472	8769	14948	30061	26360
19	5128	8778	16087	28258	7266
20+	65489	59849	92508	196667	73562

Table B.3.1 Parameter estimates of the von Bertalanffy growth equation

	Estimate	Std. error	t value	Pr(>|t|)
Linf	15.563073	0.134828	115.43	<2e-16 ***
K	0.190592	0.006698	28.45	<2e-16 ***
t0	-1.662997	0.109091	-15.24	<2e-16 ***
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1				
Residual standard error: 0.8982 on 404 degrees of freedom				

Table B.3.2. Boarfish in area VI, VII and VIII. IBTS length-frequency data converted to age-structured index by application of the common ALK.

All	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1997	9186	11460	5356	4603	4209	7331	6050	4331	4970	4375	1498	2491	1741	1248	635	1242	161	676	635	3814
1998	17475	19641	6886	6423	5693	7515	5791	3814	4860	4439	1481	2883	1654	1644	685	1240	236	917	685	4965
1999	11838	33029	20031	8826	3580	3421	2837	1990	2911	2552	804	1716	1045	1010	320	705	80	539	320	2435
2000	19340	29071	12974	18627	16220	19669	14950	10117	11553	9928	3345	5427	3955	2717	1310	2709	265	1470	1310	7757
2001	20344	44451	20694	25753	22184	16593	9665	4839	5137	4484	1492	2471	1545	1362	643	1109	175	824	643	4482
2002	10040	33131	18597	13158	9120	9171	6846	4380	6006	5313	1699	3476	2053	2046	696	1430	202	1115	696	5313
2003	840	4714	8356	20850	19443	18478	13092	7863	10801	10051	3279	7063	3662	4270	1598	2792	629	2439	1598	12890
2004	5958	5660	2092	2537	3567	8255	7560	5288	8479	8618	2871	6954	2968	4378	1924	2576	866	2794	1924	16191
2005	4201	4323	2012	2784	3836	9869	9393	6931	10296	9875	3269	7332	3684	4419	1814	2913	759	2642	1814	14728
2006	44120	35631	8054	7238	6703	8802	9417	6528	14774	15648	4994	14441	5398	9659	3847	4781	1967	6478	3847	37015
2007	24531	128029	67188	19124	7326	8707	7376	4824	8405	8454	2739	7014	2967	4520	1748	2495	799	2784	1748	15325
2008	43985	262478	172674	148047	91323	53729	31280	15702	23250	22959	7433	17778	7213	11602	5022	6177	2310	7992	5022	45589
2009	18107	42788	14748	10829	12257	14366	9760	5252	7847	7656	2476	5816	2443	3766	1259	2049	642	2128	1259	11324
2010	58552	98227	37475	25665	30828	52503	37174	21833	27440	24593	8035	15093	8215	8983	3253	6110	1257	4997	3253	25820
2011	8615	17617	17110	34003	34910	52378	39952	26259	31789	27728	9181	16113	10503	8764	3850	7350	1012	5048	3850	26631

EVHOE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1997	1876	6003	3741	3911	3938	7065	5867	4218	4832	4259	1461	2428	1699	1214	623	1215	159	659	623	3737
1998	12977	15997	6248	6247	5591	7435	5732	3777	4806	4386	1463	2843	1635	1619	676	1224	232	904	676	4888
1999	7576	31223	19915	8732	3499	3308	2715	1905	2720	2357	743	1540	975	893	285	647	62	474	285	2102
2000	17676	27730	12586	17986	15525	18740	14297	9737	11041	9490	3208	5160	3797	2556	1266	2604	253	1384	1266	7385
2001	14389	41313	20357	25467	21921	16211	9247	4525	4543	3951	1332	2057	1322	1098	578	959	153	684	578	3884
2002	6719	31728	18455	12784	8389	7115	4767	2851	3429	3018	994	1806	1123	1009	421	796	117	573	421	2964
2003	509	3993	7348	18371	17276	16113	10798	6270	7620	6852	2267	4294	2501	2456	1009	1838	326	1387	1009	7340
2004	1265	1976	1261	1722	2227	4124	3228	2061	2871	3058	1066	2426	939	1509	901	917	382	1142	901	7311
2005	2102	2603	1497	2098	3015	7160	5992	4177	5301	4873	1642	3144	1796	1776	833	1368	285	1065	833	6107
2006	35834	26593	4803	2199	1386	1489	1332	947	1521	1484	485	1170	557	725	311	445	125	464	311	2596
2007	16818	122140	65369	16986	4919	4316	2967	1715	2452	2392	788	1802	820	1124	484	678	204	715	484	4049
2008	41611	258758	168378	134061	77106	37738	18750	8277	9132	8183	2660	4868	2458	2992	1226	1876	492	1919	1226	10417
2009	13338	36829	12194	5626	5982	7788	5443	3054	4443	4230	1364	3079	1382	1965	618	1114	309	1064	618	5485
2010	33601	83903	35048	21678	23503	34210	23037	12643	16303	14519	4647	9008	4716	5551	1689	3457	690	2957	1689	14298
2011	2212	12471	14982	28729	26114	31844	23915	15535	19473	16964	5542	10176	6534	5663	2262	4513	597	3197	2262	16235

IGFS+WCSGFS+EVHOE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
2003	636	4552	8306	20803	19406	18414	13013	7804	10668	9916	3237	6942	3612	4190	1573	2752	617	2393	1573	12654
2004	1685	3414	1912	2444	3481	8017	7255	5037	8031	8189	2735	6610	2796	4164	1860	2446	838	2683	1860	15644
2005	2930	3604	1895	2694	3773	9738	9200	6777	9949	9514	3154	7004	3553	4203	1731	2801	721	2505	1731	13978
2006	36687	28176	6830	7100	6633	8714	9277	6421	14479	15337	4898	14144	5288	9457	3779	4686	1933	6356	3779	36365
2007	17873	124020	66810	18929	7205	8648	7322	4790	8309	8353	2708	6917	2932	4453	1729	2464	788	2746	1729	15126
2008	42240	260577	172031	147113	90691	53328	31023	15587	22918	22641	7344	17496	7113	11395	4967	6101	2285	7861	4967	44972
2009	13607	37705	13658	10616	12063	14060	9426	5030	7283	7072	2296	5275	2243	3396	1141	1878	582	1909	1141	10185
2010	33976	84649	35967	24858	30441	52245	36921	21671	26982	23992	7828	14456	8055	8546	3060	5910	1145	4712	3060	24053
2011	2884	13954	16666	33742	34724	52174	39716	26089	31387	27290	9039	15699	10356	8486	3752	7213	958	4882	3752	25707

SPNGFS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1997	7306	5446	1609	681	249	203	121	67	69	56	18	22	18	11	4	11	0	6	4	23
1998	4493	3640	638	175	101	79	58	37	54	53	17	40	19	25	9	15	4	14	9	77
1999	4258	1802	116	93	80	112	121	85	191	195	61	175	70	117	35	58	18	65	35	333
2000	1661	1325	347	518	553	750	537	315	443	379	116	237	139	146	37	91	10	78	37	325
2001	5952	3099	308	205	161	197	190	148	199	175	58	114	77	62	25	53	6	34	25	169
2002	3315	1395	104	54	43	55	63	47	98	88	26	71	37	46	10	25	3	24	10	97
2003	203	155	38	26	16	14	10	5	9	9	3	7	3	4	2	2	1	3	2	15
2004	4267	2243	177	82	68	171	219	186	303	279	89	209	118	124	37	85	14	63	37	294
2005	1253	701	108	78	46	50	60	51	84	78	25	59	33	35	15	24	4	22	15	116
2006	7297	7378	1191	85	34	36	56	44	116	112	33	100	43	68	14	32	8	35	14	154
2007	6646	3990	367	180	106	37	30	18	55	54	16	50	20	35	8	15	4	20	8	92
2008	1736	1886	629	908	597	329	178	62	202	183	47	158	53	122	28	36	10	81	28	352
2009	4487	5077	1085	168	104	79	71	26	174	155	37	147	56	113	9	34	6	58	9	194
2010	24558	13572	1504	792	346	101	85	41	222	365	132	436	76	306	146	130	91	206	146	1347
2011	5730	3656	432	244	163	94	77	38	140	182	61	198	48	140	50	59	33	84	50	493

Table C1.1. Boarfish in ICES Subareas V, VI, VII, VIII. Pseudo-cohort derived estimates of fishing mortality (F) and total mortality (Z), in comparison with total landings per year. Pearson correlation coefficient of F vs. landings (tonnes) indicated.

Age	2007	2008	2009	2010	2007	2008	2009	2010
	Raised numbers				ln (raised numbers)			
1	0	0	811	2357	0	0	6.70	7.77
2	300	3409	12178	10920	6	8	9.41	9.30
3	1802	13131	53429	70355	7	9	10.89	11.16
4	34813	65576	280711	285073	10	11	12.55	12.56
5	41685	87766	376001	547678	11	11	12.84	13.21
6	53444	121331	399128	840426	11	12	12.90	13.64
7	22269	64616	225921	498521	10	11	12.33	13.12
8	25366	41348	124939	279757	10	11	11.74	12.54
9	47786	33019	115741	262589	11	10	11.66	12.48
10	38242	29127	98574	220652	11	10	11.50	12.30
11	11947	9496	31662	74686	9	9	10.36	11.22
12	27576	13154	47676	109351	10	9	10.77	11.60
13	4132	7363	30715	56865	8	9	10.33	10.95
14	14349	8429	25502	56473	10	9	10.15	10.94
15	6534	5480	12924	25763	9	9	9.47	10.16
16	11947	6539	23006	51295	9	9	10.04	10.85
17	6534	3778	4857	12731	9	8	8.49	9.45
18	6534	6159	13919	28692	9	9	9.54	10.26
19	4484	6165	15022	26819	8	9	9.62	10.20
20+	57267	42035	86047	187661	11	11	11.36	12.14
Z					0.17	0.23	0.27	0.28
F (Z-M), where M = 0.16					0.01	0.07	0.11	0.12
Landings (t)					18387	24683	83688	137503
Correllation coefficient landings vs. F					0.83			

Table C 1.2. Boarfish in ICES Subareas V, VI, VII, VIII. Results of VIT pseudo-cohort analysis based on 2010 mortality estimates.

Catch mean age	8.66
Catch mean length	12.81
Mean F	0.14
Mean Z	0.3
Number of recruits, R	52 752
Spawning Stock Biomass, SSB	2 053 583 t
Total Stock Biomass, SSB	2 814 472 t

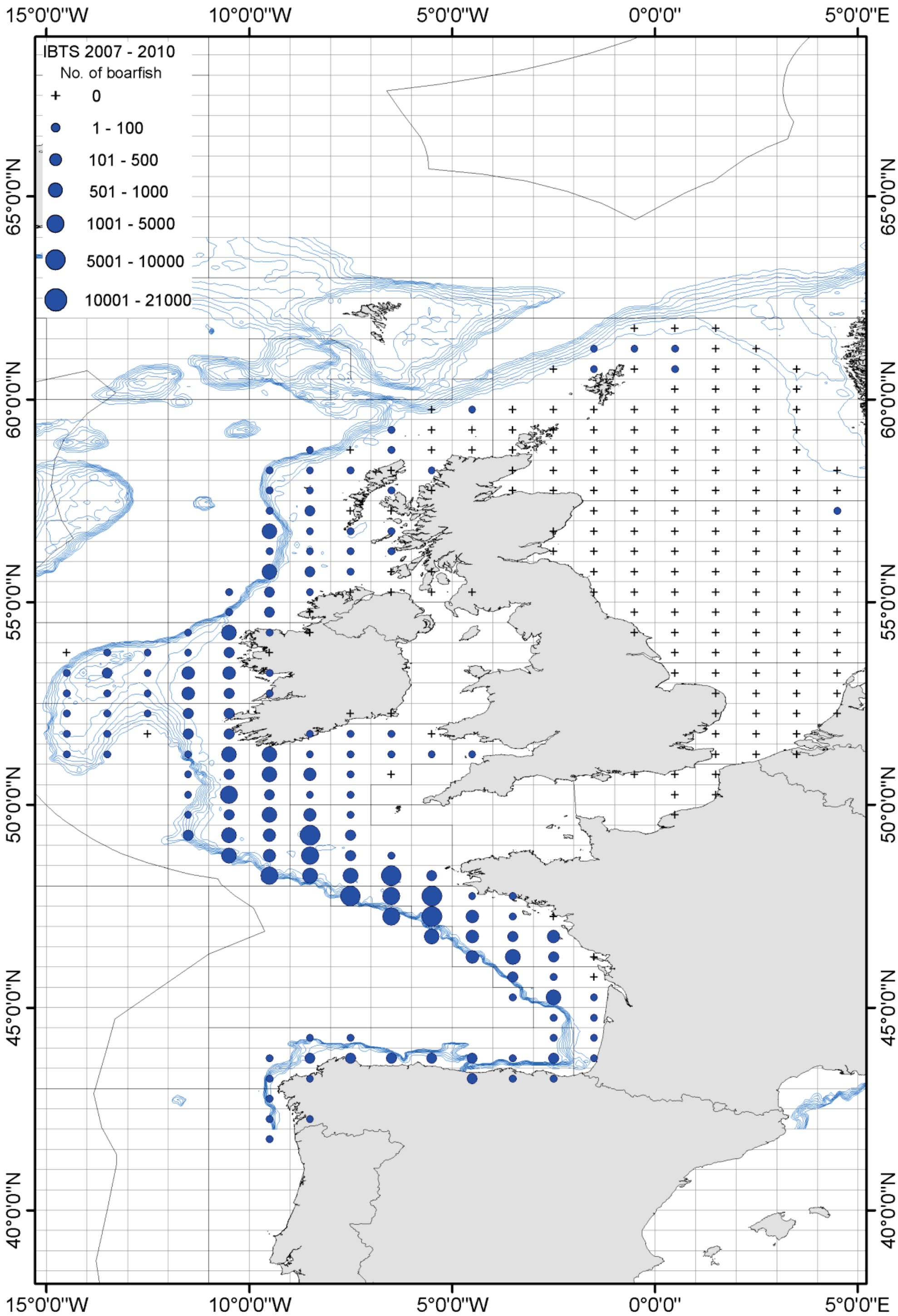


Figure A.1.1 Boarfish in ICES Subareas V, VI, VII, VIII. Distribution of boarfish in the NE Atlantic showing proposed management area.

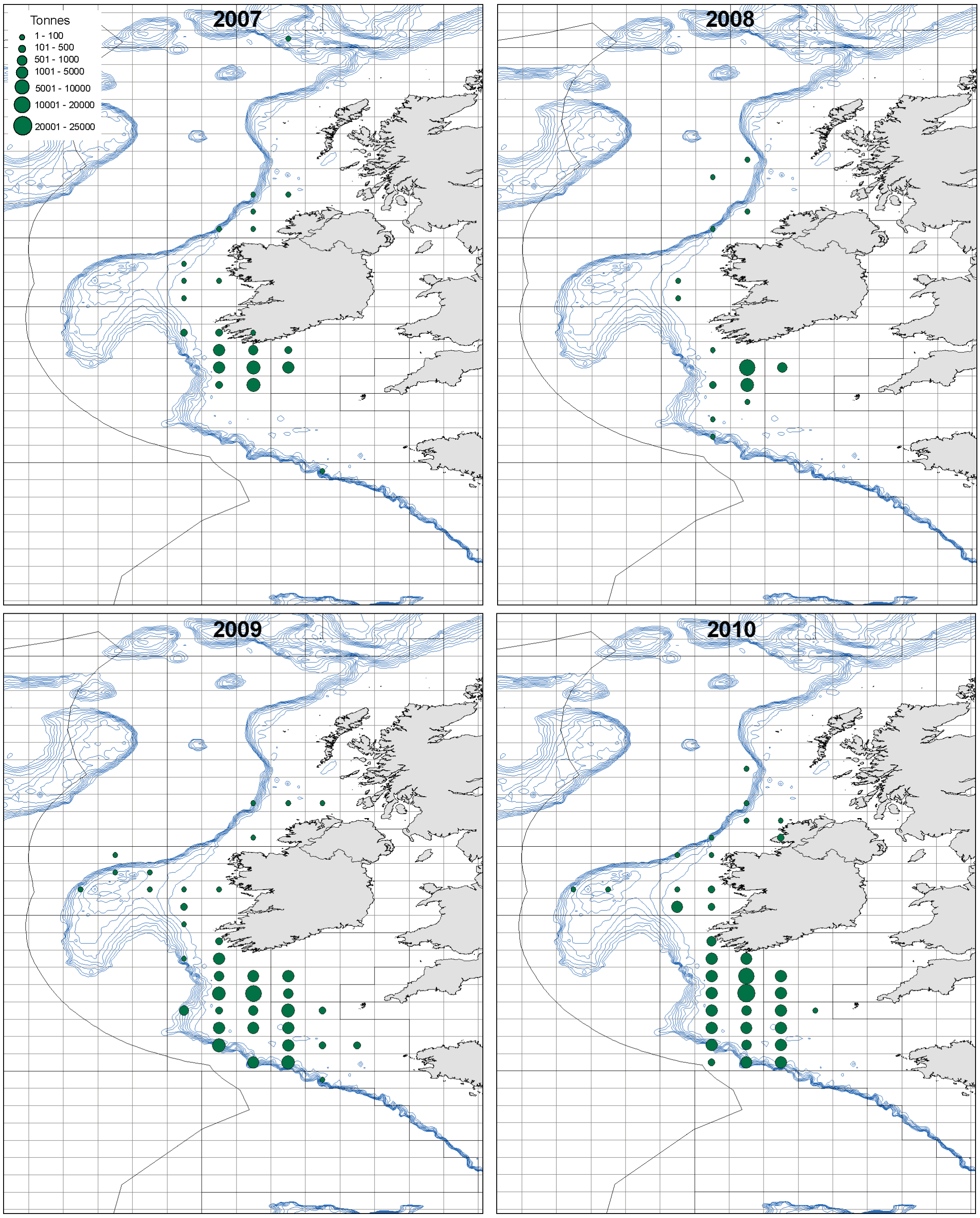


Figure A.1.2. Boarfish in ICES Subareas V, VI, VII, VIII. Irish catches by rectangle and year .

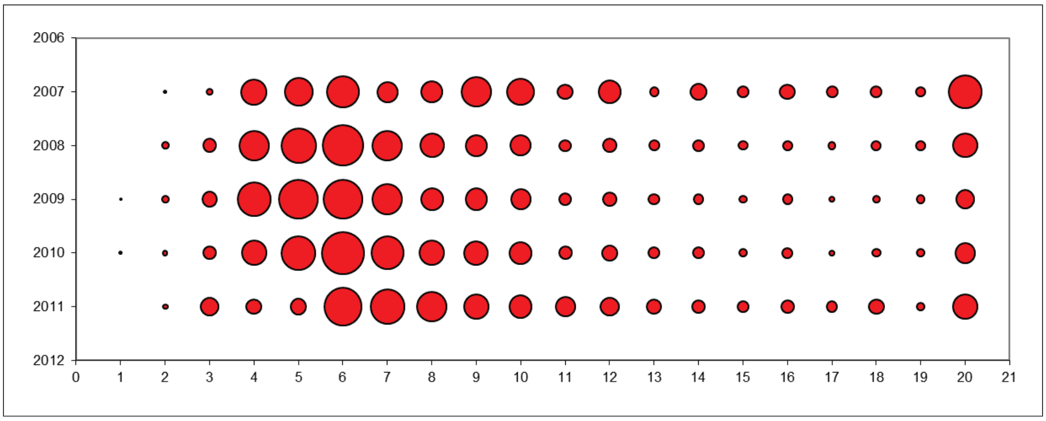


Figure B.2.1. Boarfish in ICES Subareas V, VI, VII, VIII. Catch numbers-at-age standardised by early mean. 20+ is the plus group.

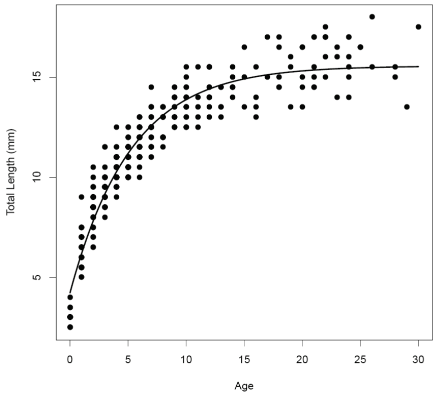


Figure B.3.1 von Bertalanffy growth curve; see Table B.3.1 for parameter estimates

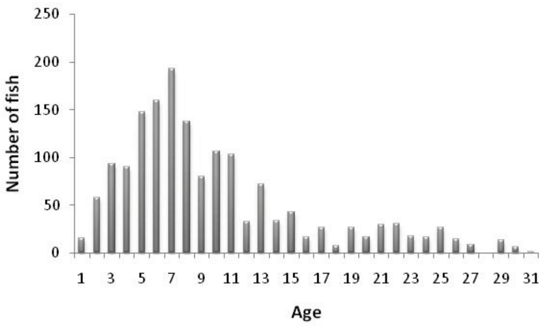


Figure B.3.2 Age distribution for n=1633 fish sampled

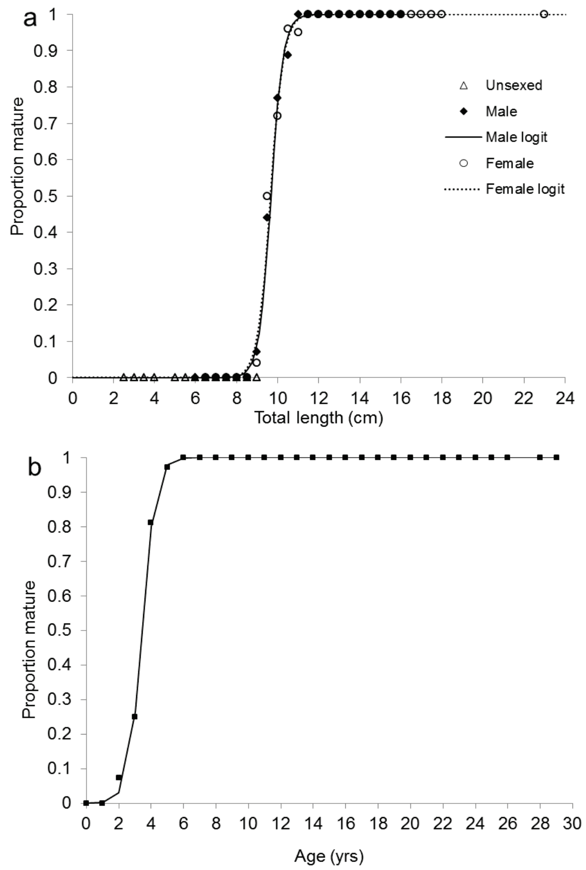


Figure B.3.3 Maturity ogives for (a) total length and (b) age for boarfish

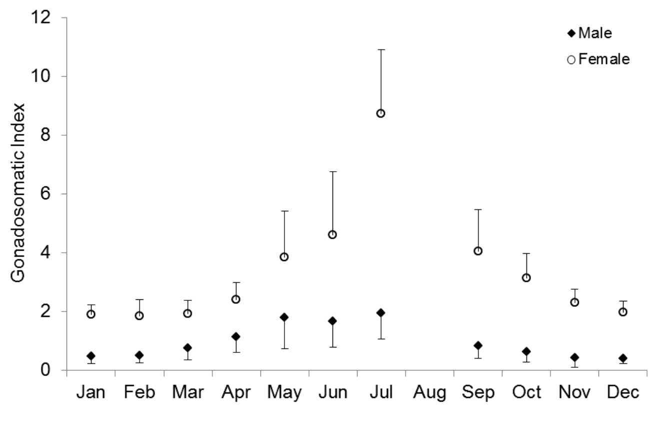


Figure B.3.4 Gonadosomatic index for male and female boarfish

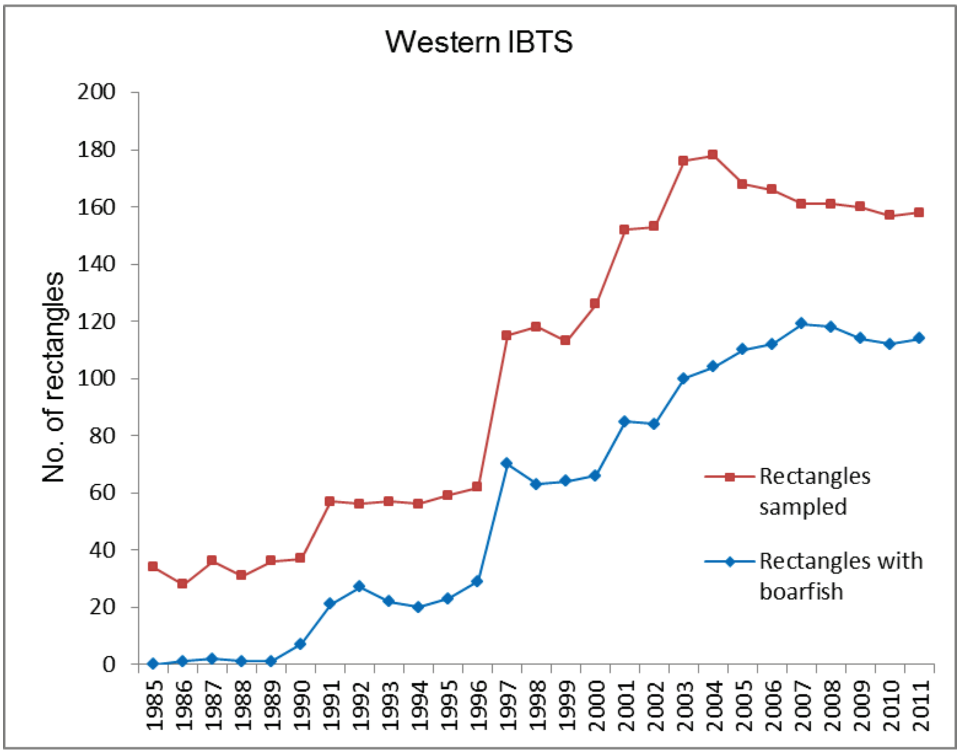


Figure B.4.1 Occurrence of boarfish in ICES Rectangles sampled during the western IBTS 1985 – 2011.

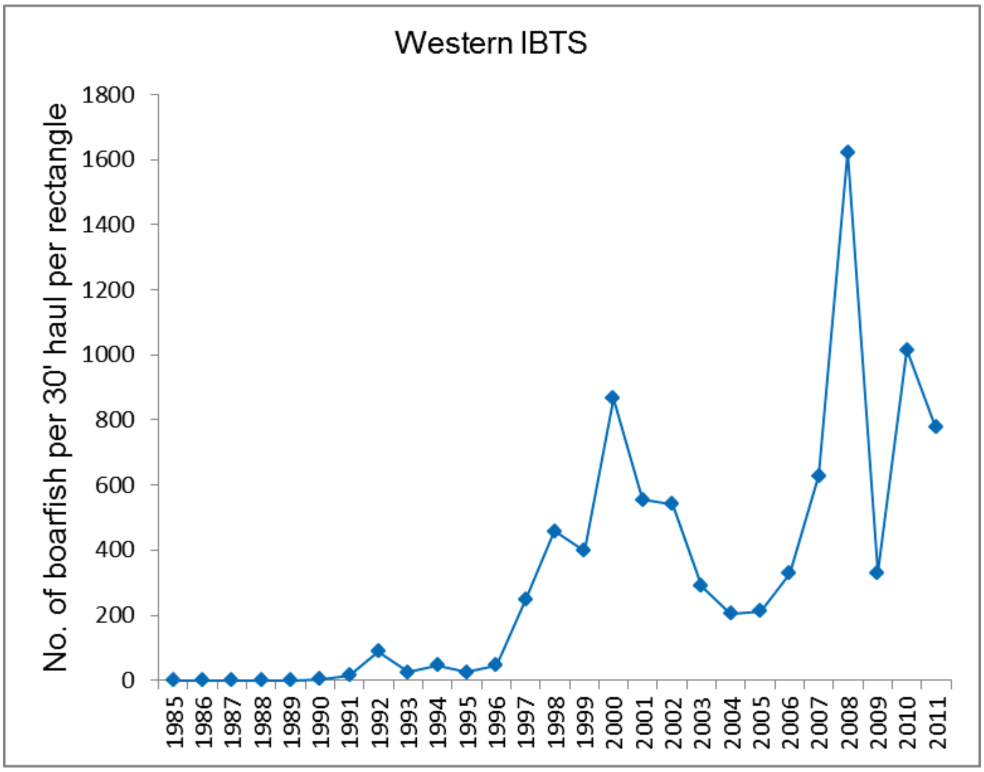


Figure B.4.2 Boarfish in ICES Subareas VI, VII, VIII. CPUE in number per 30 minute haul of boarfish per rectangle in the western IBTS survey 1985 to 2011.

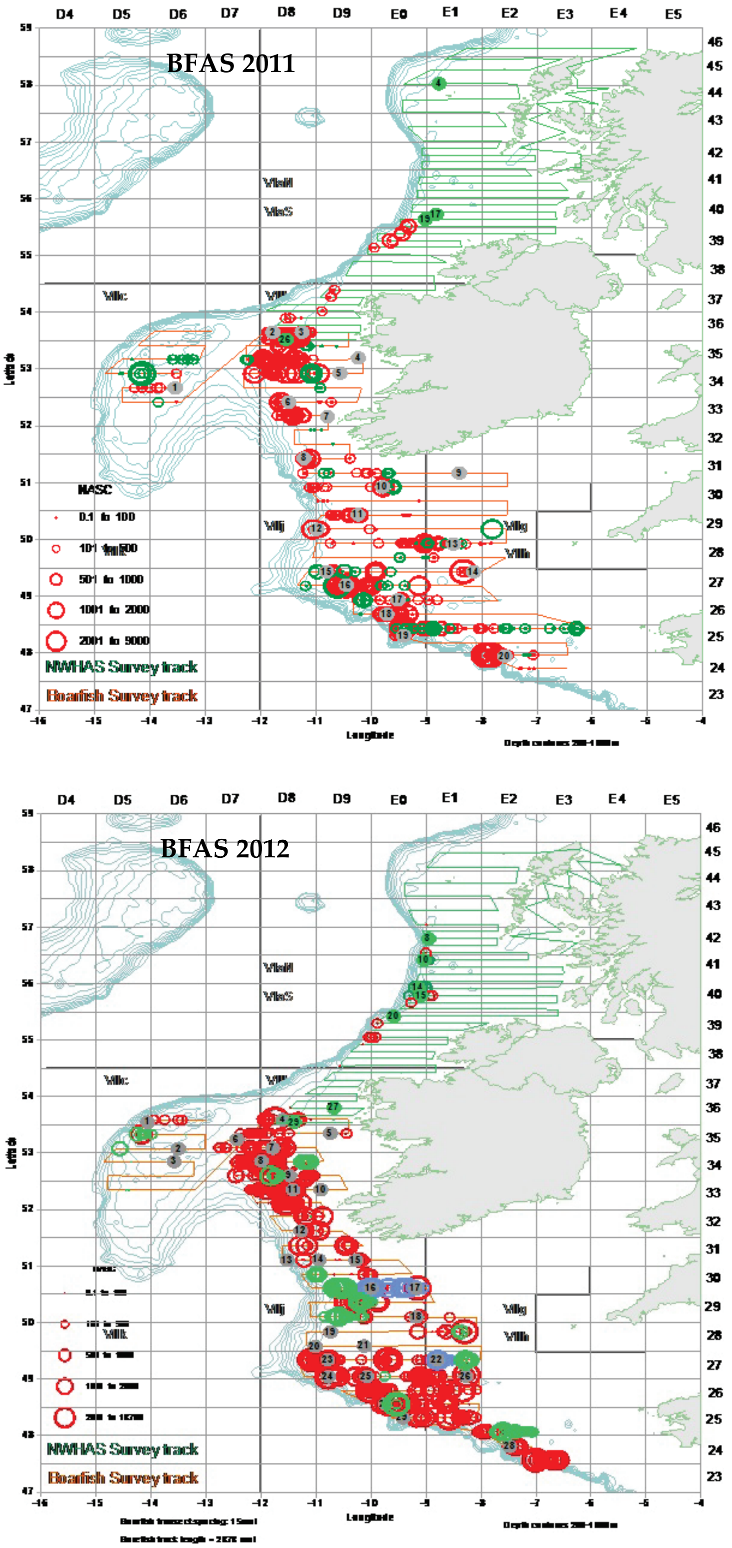


Figure B.4.2.1. Boarfish acoustic survey track and haul positions from acoustic survey (top) July 2011, (bottom) July 2012.

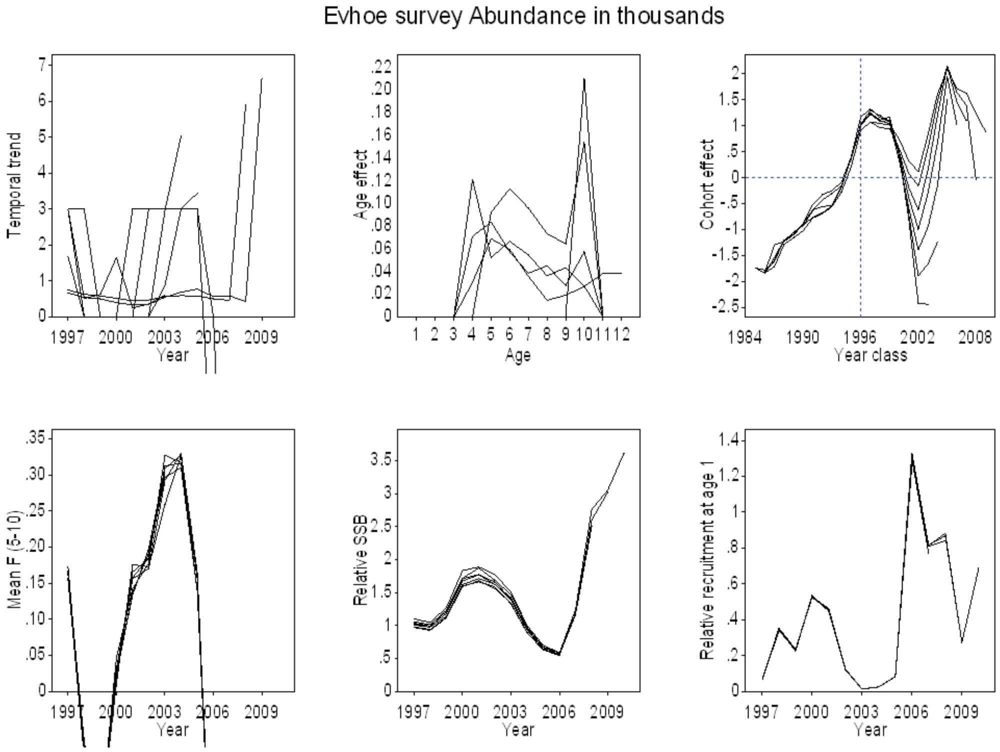


Figure C.1 Boarfish in ICES Subareas V, VI, VII, VIII. Results of exploratory SURBA run, using the EVHOE survey as a relative index of abundance.

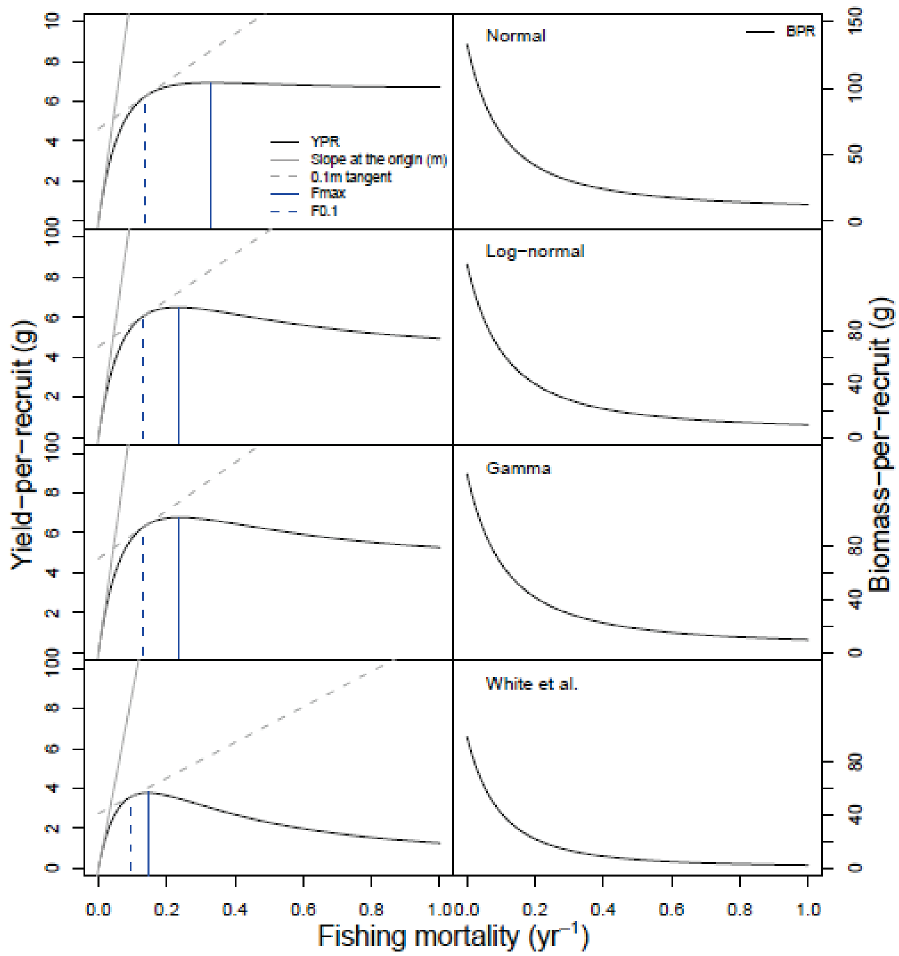


Figure E.1 Boarfish in ICES Subareas V, VI, VII, VIII. Results of exploratory yield per recruit analysis. Beverton and Holt model applied to various fits of the VBGF and for comparison with the VBGF parameters provided by White et al. 2011.

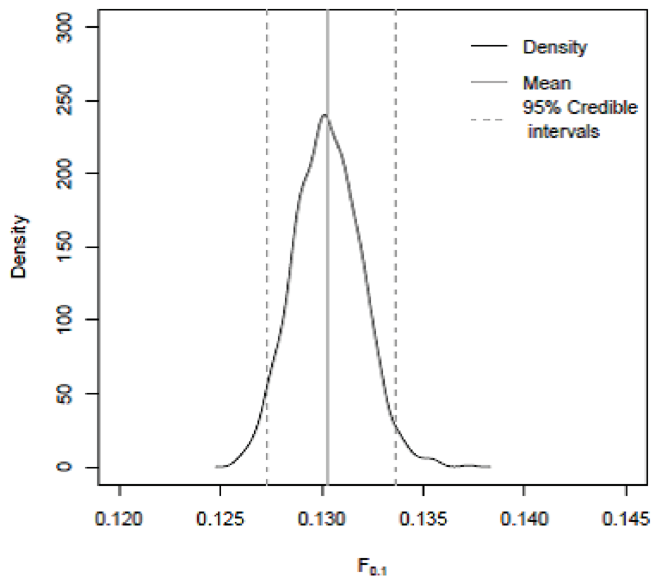


Figure E.2 Boarfish in ICES Subareas V, VI, VII, VIII. Sensitivity of estimation of $F_{0.1}$.

Annex 3 Special Requests

Exploring the sensitivity of the ICA assessment of NEA mackerel to misreporting in historic catches

David C.M. Miller and Claus R. Sparrevohn

WGWIDE Aug-Sep 2013

The Request

The Coastal States refer to the ICES advice on Northeast Atlantic mackerel for 2013 where it states that: "Unreported catches in the time-series cause underestimation of stock size in the analytical assessment, which is the basis of the scientific advice. The level of misreporting may have changed over time. This will remain a problem for future years, as the model cannot compensate for an unknown level of historical unreported catches." (ICES Advice 2012, Book 9, pg. 9).

Based on this

1) ICES is requested to explore and evaluate the sensitivity of the current assessment to past uncertainties in the estimates of removals.

Introduction

Anecdotal information, supported by some hard evidence, suggests that the official fish removal statistics from the mackerel fishery have in the past underestimated the actual removals. This historic misreporting is also a problem for current attempts to estimate stock size since erroneous catch statistics will result in a potentially erroneous perception of the stock. This will in turn impact on the short term forecast of the stock and thereby the advice on future fishing opportunities.

At WGWIDE 2013, it was decided to abandon the use of the ICA model for the assessment of NEA mackerel. Given this decision, there is limited value in evaluating the sensitivity of the **current** assessment to past uncertainties in the estimates of removals. The handling of catch data is specific to the particular model type being used for an assessment and it is unlikely that ICA will still be used in the assessment of the stock following the benchmark assessment in 2014. Nevertheless, it was decided that a broad analysis of the potential impacts of misreporting could be made.

Mackerel catch data

The reported catch data for NEA mackerel is considered an underestimate due to limited accounting for discarding, slippage, and illegal, unregulated, and unreported (IUU) catches (ICES 2006, Remøy et al. 2003, Simmonds et al. 2010, mackerel fishing industry representatives (WKNAMMM) *pers comm.*).

Observer coverage of the fleets fishing for mackerel has never been adequate. For most fleets there are no reliable estimates of discarding and slippage. Though discarding rates are likely to vary between fleets, estimates of discards from the Netherlands over the period 2003-2012 range from 16-37% of the landed catches. Slippage, because of mixed catches or excess catch, is a challenge to estimate regardless of the presence of observers. Highgrading, the process in which, typically the larger individuals are sorted from the catch and kept while those smaller are discarded, is equally difficult to estimate but is believed to be a problem in the mackerel fishery. Finally, black landings where a certain proportion of the fish is bypassed the official registration has also been a reality in some countries.

It is standard practice that in the process of taking the mackerel from the fishing vessel to the means of transport or the processing factory, a certain percentage of the landed weight is subtracted as water. This percentage is called the 'water content' and has prior to 2003 varied substantial between countries and years and has been as high as 10-15%. After 2003 the water content has been fixed to 2 % by a EU directive and agreement with Norway. This would lead to a relative underreporting of actually landed mackerel for the period prior to 2003 compared to present reported landings.

Simmonds et al (2010) found that to reconcile mortality estimated from the different fishery independent datasets for the period up to 2007, the landings and discards reported would have to have been between 1.7 and 3.6 times higher than the recorded catches. At the WKNAMM meeting at ICES headquarters in February 2013 (ICES 2013a), the mackerel fishing industry representatives acknowledged that the official reported catches are an underestimate of actual removals. However, they were not in a position to provide more realistic numbers as such records do not exist.

Since it is not possible to reconstruct exact values or estimates from the past, this report attempts to estimate qualitative trends in underreporting over time. This is done by dividing the NEA mackerel fishery into four temporal regimes/periods where the discrepancy between official statistics and true removals is thought to have differed. The regimes are identified from anecdotal information, and official EU and Norwegian regulations. The level of likely misreporting was primarily based on the estimated levels from Simmonds *et al.* (2010), adjusted according to the working group's opinion of the likely levels of misreporting during the four time periods, and the differences in water content percentage used over time.

1980s: Klondyking

During the 1980s there was a period known as the Klondyking period. During this period the fishery was to a large extend uncontrolled as mackerel was delivered directly from fishing vessels involved in the catch to factory vessels located offshore. Most factory vessels originated form countries within the former eastern block and this, combined with the offshore delivery, made the fishery virtually unregulated. This period ended rather abruptly around 1989, concurrent with the fall of first the Berlin wall, and then the eastern block. During this period, anecdotal evidence suggests that the unreported component of the catch was likely to have the same age structure as the reported catch. This is based upon the fact that the fishery was essentially not restricted by a maximum landings limit and the price for the mackerel in this fishery was very low at the time.

1990s: Japanese market highgrading

Subsequent to the Klondyking came a period which to a large extend was influenced by large size specific price differences. Such a size specific price difference combined with a TAC system creates a motivation for highgrading. The size specific price was a result of a demand for large mackerel (larger than 600 g) from the Japanese market. Attempts to reconstruct this price differences and use this as an index for the motivation to highgrade were made but no reliable data could be found. However, that highgrading was a problem at least up to 1999 is illustrated by a Norwegian regulation, in that year, where it was decided that only a certain (and variable) fraction of landed mackerel larger than 600 g would achieve the highest price. Such a law was designed to diminish the motivation for highgrading, and, independent of whether the regulation was effective or not, it at least implies that the problem was present prior to 1999. During this period the unreported component of the catch is likely to consist of smaller and hence younger individuals the larger, older fish.

Early 2000s: Uncontrolled IUU

In Scotland, discrepancies between official declared landings and the tonnages reported as processed by the factories were found to be large (factor of 1.6, ICES 2006). An analysis of Irish export figures estimated an overquota factor of 1.7 for the period 1988–2002 (Remøy et al. 2003), though these findings were contested (Marine Times 2003). It is unsure how the age structure of the unreported component compared to the reported catch during this period.

2006 onwards: 'Golden age' period

Since 2005 the discrepancy between official landing statistics and the true removals is believed to be relatively low compared to the earlier period described. However, Dutch discard estimates clearly show that some under reporting is still occurring. How these estimates relate to discarding rates of the rest of the fleet is uncertain.

The ICA assessment model

The ICA (Integrated Catch Analysis) assessment model consists of two main parts: a recent separable period and a VPA constructed past (Figure 1). These periods make two main assumptions when handling catch data. The VPA period assumes that catch at age estimates are exactly known. For the separable period, it is assumed that fishery selectivity at age is constant over the whole period (the last 12 years).

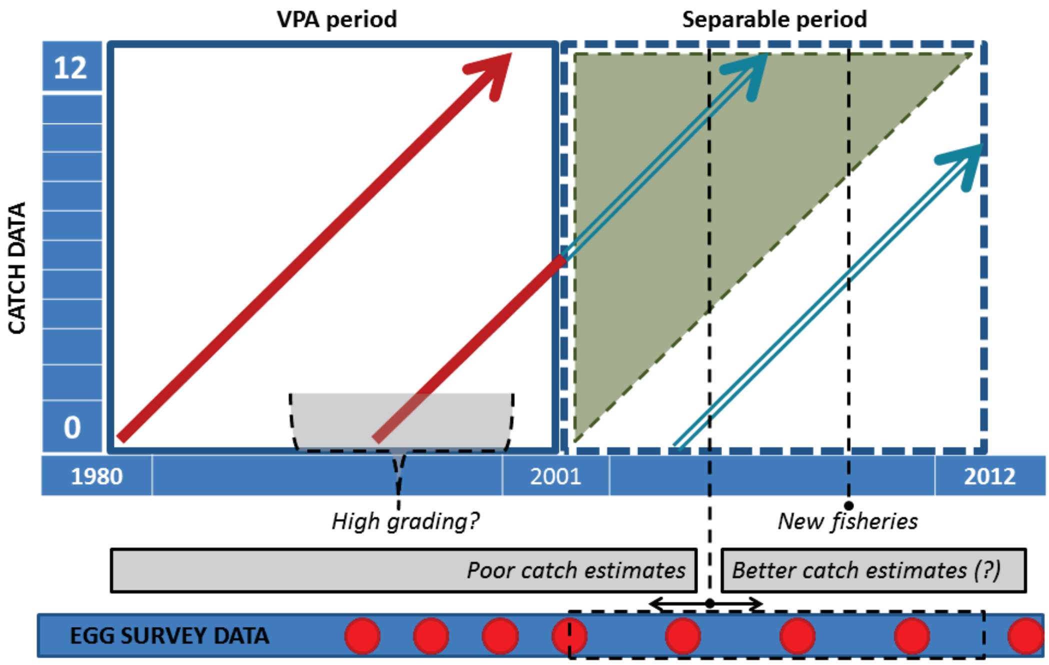


Figure 1. A schematic of the main features of the Integrated Catch at Age (ICA) model.

In Figure 1, the red arrow indicates a cohort where abundance and F estimates depend on the assumption of exact catch data, the hollow blue arrow indicate a cohort where these estimates depend on the assumption of constant selectivity, and the combination arrow indicates a cohort where these estimates depend on both assumptions. The grey shaded triangle indicates a selection of log catch residuals at age that are significantly smaller than the remaining residuals in the recent ICA fit to the data. This indicates that the selectivity pattern used in the separable period fits tighter to the cohorts that originate from the VPA period. This corresponds to a period where catch data are considered poor and there is strong potential that high grading occurred.

The assumption that catches are exactly known is one of the biggest criticisms of all VPA models, since this is very rarely considered to hold true. It is certainly not true in the case of mackerel. If the degree to which the catch at age estimates are wrong is constant over time, the trends coming out of a VPA assessment would still be acceptable. Even this assumption may not hold true in the case of mackerel. However, since the last benchmark, and the evaluation of the management plan, the consensus was that, assuming a constant proportion of unaccounted mortality, the SSB from ICA was indicative of the trend in the real SSB, and the estimated F was reliable.

The assumption of constant selectivity during the separable window is unlikely to be true for the mackerel fishery, which has changed significantly in the recent past. Over the last 12 years (the duration of the separable window), the expansion of the stock into new waters has lead to the introduction of new fishing fleets catching mackerel in new fishing areas. Most of these new fleets fish for mackerel using similar gears as the other major fleets. However, they fish at a different time of the year when the fish are more disaggregated and in areas where a higher proportion of larger mackerel are likely to occur (since larger mackerel are considered to migrate further). Catches in the northern areas (II, V, XIV) now form a greater proportion of overall catches. Additionally catch reporting is assumed to have changed within the separable window. Hence it is likely that the assumption of constant selectivity made by the ICA model is violated.

Three egg survey estimates were made during the VPA period of the model (Figure 1). Since the VPA period is incapable of producing an accurate estimate of stock size and trend with the given catch data, this has a knock-on effect into the separable period since the catchability model for the index will be influenced by how these three data points relate to the estimated stock size in the VPA period.

Methods

New catch time series (N=100) were generated based on the reported catch and estimates of misreporting factors. Data up to and including 2011 were used (i.e. as was done for the 2012 assessment of the mackerel stock). The ICA was then run using the same settings as described in the stock annex for each of the new catch time series. The R code used to run the analyses is included in Appendix A.

Once the four periods of misreporting had been defined, ranges of likely misreporting factors were set for each period by the working group (Table 1.) For each year in the catch time series, a misreporting factor was randomly selected from a uniform distribution between the relevant lower and upper bound.

Table 1. Estimated ranges of misreporting during the four time periods considered.

Period	Year Range	Misreporting Factor	
		Lower bound	*Upper bound*
Klondyking	1972 – 1989	1.7	3.6
Japanese market highgrading	1990 – 2000	1.7	2.5
Uncontrolled IUU	2001 – 2005	1.1	1.7
'Golden age'	2006- 2011	1	1.1

Water content values used historically are shown in Table 2. No value was known for the period prior to 1986. Based on the assumption that the currently used 2% is an accurate estimate of the quantity of water included in catches, any percentage of water content used above this level is accounted for in the catch adjustment factor, e.g., when 10% was used between 1986 and 1999, 10-2=8% of this was likely to be mackerel, not water. Hence the catch during this period is multiplied by 1.08. These water content factors were added in addition to the misreporting factors sampled from Table 1.

Table 2. Water content values used historically for the mackerel fishery.

	1972-1985	1986-1999	2000-2003	2004 onwards
Water content %	???	10%	13%	2%
Catch adjustment factor	1	1.08	1.11	1

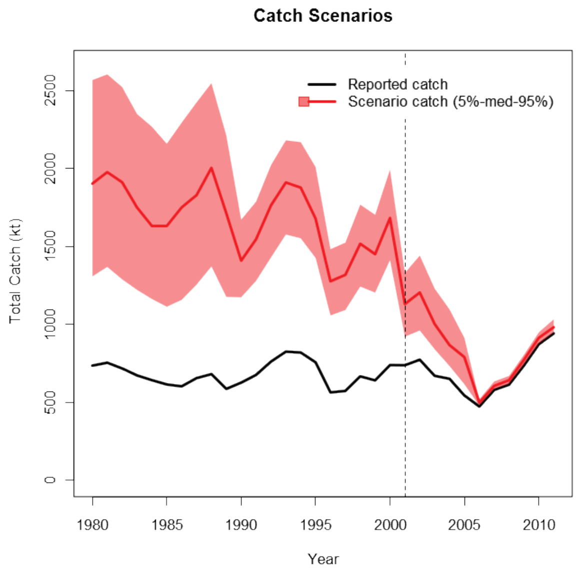
As a sensitivity test, an additional 100 time series of catch were created assuming a constant age structured bias in misreporting of catches (Table 3). These time series of estimated catch assumed the same total catch (including misreporting factors and water content corrections had been applied to the reported catch) but distributed the misreporting more over the young ages. The values in Table 3 were use to multiply up the numbers at age in the catch matrix. Following this a SOP (sum of products) correction was done to ensure that the total catch weight in each year was the same.

Table 3. Vector of possible relative misreporting by age.

Age:	**0**	**1**	**2**	**3**	**4**	**5+**
Relative contribution to misreporting	1.5	1.3	1.3	1.2	1.1	1

Results

The resultant distribution of total catch for the 100 scenarios in comparison with the reported catch is shown in Figure 2. The high estimated rates of misreporting prior to 2000 result in both quantitative and qualitative differences in catch level. The reported catch is remarkably stable over time for a pelagic species and indicates that recent removals are amongst the highest in the time series. Conversely, the estimated catch fluctuates at a higher level prior to 2000 before declining. This results in the catches in recent years being amongst the lowest in the time series. Figure 3 compares the inputted catch levels with the catch estimated by the model. These are identical during the VPA period, but differ in the separable period (last 12 years) when catch is not taken as exact and constant selectivity is assumed. In the separable period, the fishing mortality applied to the numbers at age in the ICA model produces model estimated values for catch in those years that may differ from the inputted catch data. For the last three years the model fit estimates that catches are lower than those estimated.



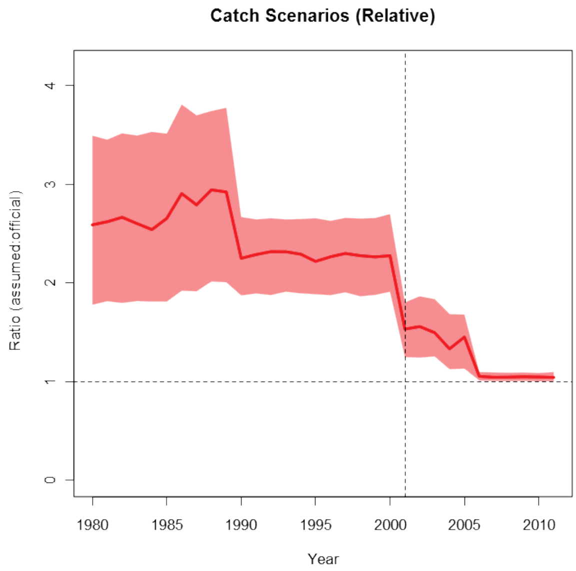


Figure 2. Reported (black) and estimated (red; 'scenario') catch (left) and the relative difference between the two (right). The shaded area represents the 5-95% range. The vertical dashed line indicates the start of the separable period in the ICA model.

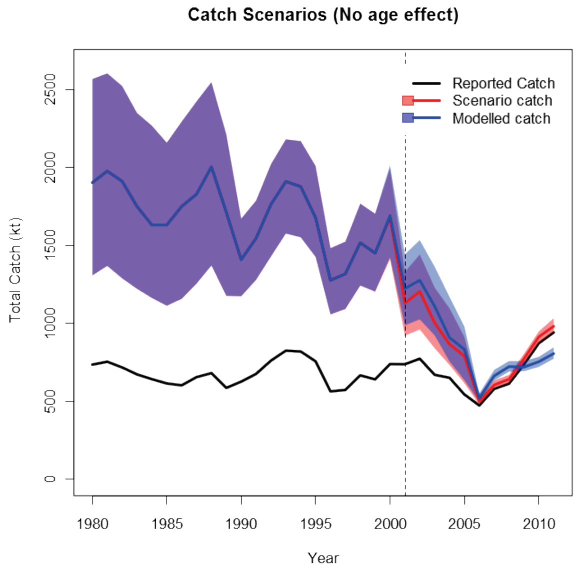
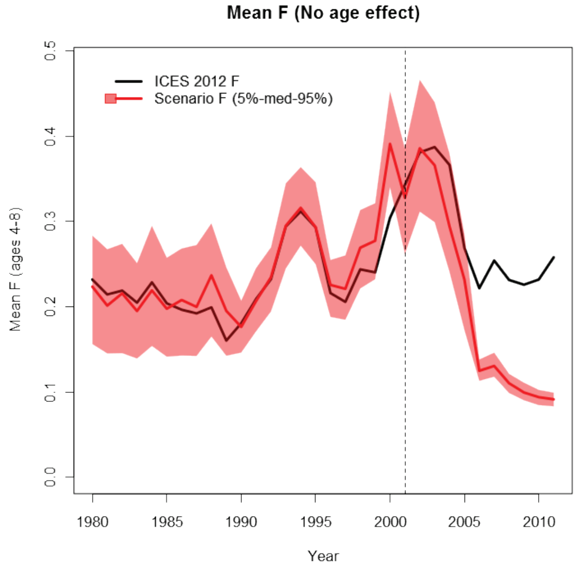
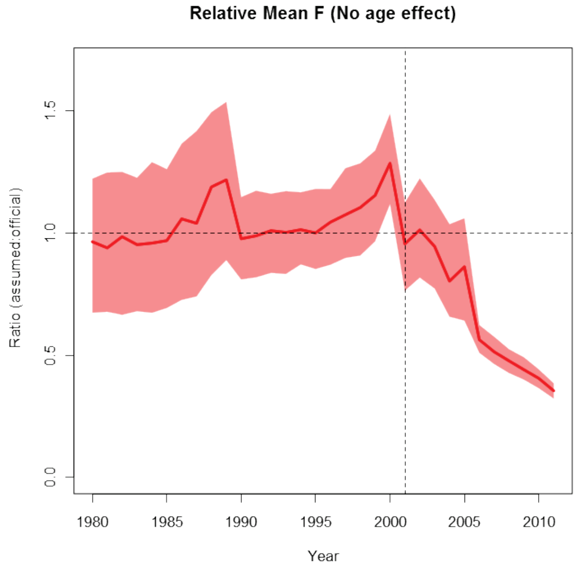
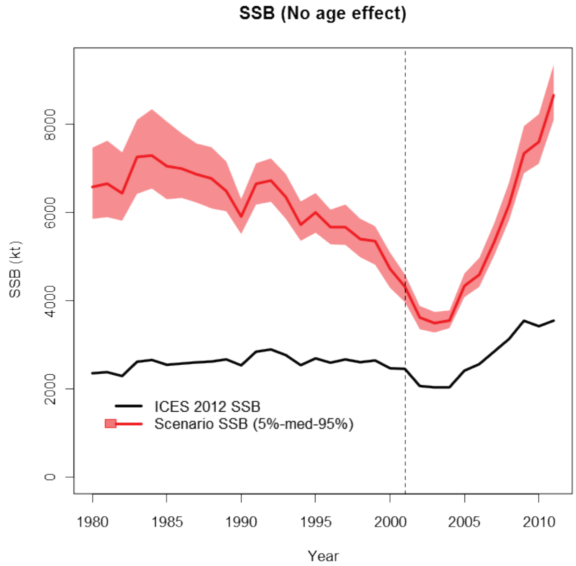


Figure 3. Reported (black), estimated (red) and model fit (blue) total catch. The shaded areas represents the 5-95% range. The vertical dashed line indicates the start of the separable period in the ICA model.

Figure 4 shows the resulting stock metrics (mean F, SSB and recruitment) from the ICA models fit to the reported and estimated catch data. Using the estimated catch time series results in similar estimates of F during the VPA period, but lower estimates of F during the separable period. The degree to which mean F is overestimated using the reported catch (relative to the estimated catch) increases in the most recent years. SSB is estimated to be significantly higher using the estimated catches. The degree to which SSB differs is highest during the Klondyking period and decreases as the level of misreporting is estimated to decrease. Conversely to the pattern in mean F, the degree to which SSB is underestimated using the reported catch (relative to the estimated catch) increases in the most recent years. Similarly to the SSB, recruitment levels are scaled up when estimates of misreporting are taken into account.


Mean F (No age effect)
ICES 2012 F
Scenario F (5%-med-95%)
Mean F (ages 4-8)
0.0
0.1
0.2
0.3
0.4
0.5
1980
1985
1990
1995
2000
2005
2010
Year


Relative Mean F (No age effect)
Ratio (assumed:official)
0.0
0.5
1.0
1.5
1980
1985
1990
1995
2000
2005
2010
Year


SSB (No age effect)
ICES 2012 SSB
Scenario SSB (5%-med-95%)
SSB (kt)
0
2000
4000
6000
8000
1980
1985
1990
1995
2000
2005
2010
Year

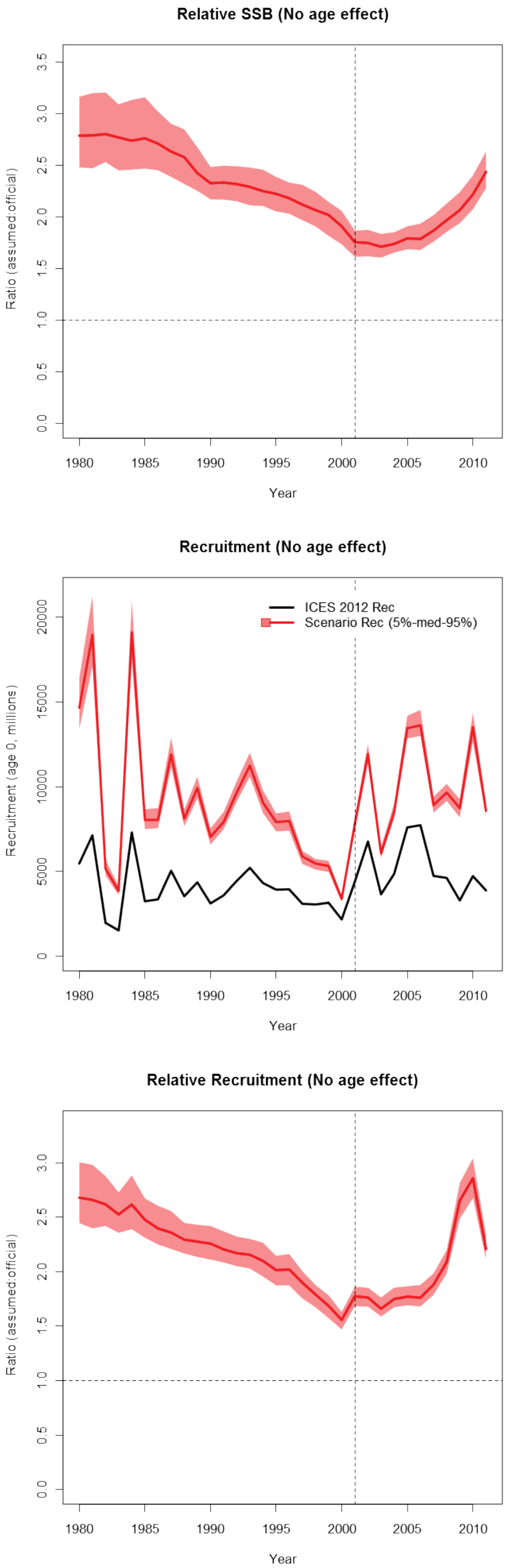
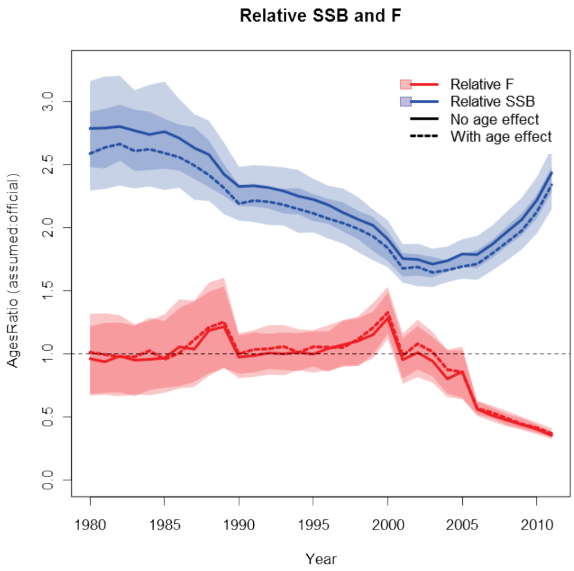


Figure 4. Comparison of absolute (left) and relative (right) outputs from ICA assessments using the reported (black) and estimated (red) catch time series: Mean fishing mortality for ages 4-8 (top), spawner stock biomass (middle) and recruitment (bottom). The shaded areas represents the 5-95% range. The vertical dashed line indicates the start of the separable period in the ICA model.

Figure 5 shows a comparison of the results with and without an age effect in misreporting. The patterns in mean F, SSB and recruitment are all very similar. Likewise for mean F and recruitment the absolute values estimated are very similar. Only for SSB is a slightl scaling difference observed, with the catch estimates including a higher degree of younger fish in the misreported component resulting in slightly lower estimates of SSB.



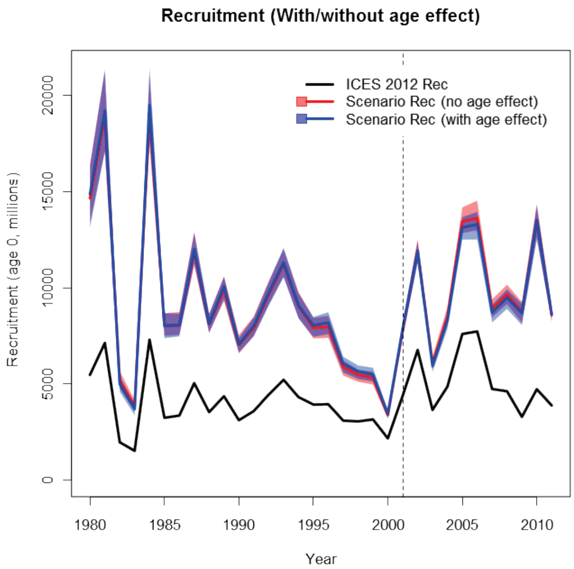


Figure 5. Comparison of assessment outputs assuming catch misreporting with or without an age effect. Left: the relative change in SSB (blue) and Mean F (red) compared to the assessment using reported catch with (dashed) and without (solid) an age effect in misreporting. Right: absolute estimates of recruitment with (blue) and without (red) an age effect in the misreporting. The shaded areas represents the 5-95% range. The vertical dashed line indicates the start of the separable period in the ICA model.

Discussion

The catch levels estimated form the misreporting scenarios show a very different pattern from the reported catch. Since all reported catch values were assumed to be underestimates, the estimated catch values are higher than reported values, becoming more similar with time. While the reported catch suggests that current levels are the highest of the time series, the estimated levels show recent years to be amongst the lowest. This is a significant qualitative difference that not surprisingly produces different patterns in the estimated levels of fishing mortality and spawner stock biomass.

Most of the scaling that occurs with the higher estimated catches is observed in the estimates of recruitment and SSB. The SSB values that result from the assessment fit to the estimated catch values are significantly higher than those from the current ICA assessment and are more in line with levels estimated from other data series (e.g. absolute SSB estimates from the egg survey (ICES 2013b) and the IESSNS swept area survey).

Mean F is similar over the period prior to 2000. However, as the level of misreporting is assumed to be more accurate the degree to which F is overestimated by the current assessment increases relative to the assessment using the estimated catch values. At previous WGWIDE meetings the conclusions of Simmonds et al. (2010) that the level of fishing mortality and trends in SSB are likely to be robust to the misreporting in catch were used as a rationale for continuing to use the ICA assessment. However, Simmonds et al. (2010) only used data up to 2007. Since then catches are assumed to be reported more accurately in the past. The results here indicate that this leads to a deviation from the assumption of accurate F estimation in recent years. Also, when the level of misreporting is assumed to vary over time, the trends in SSB are no longer accurately estimated either.

The estimated catch levels generated here are considered to be broadly representative of the true history of catch in this fishery. However, the level of quantitative accuracy for any given year is likely to be poor. Also, in the absence of good data, the current level of misreporting cannot be accurately estimated. The conclusions of this sensitivity analysis to a large degree depend on the assumption that recent catch is better estimated relative to the past. However, the last 5 years have seen conditions that would allow opportunities for highgrading: an apparently growing stock, with large incoming year classes and potential limiting TACs for the fishery. However, assuming that the levels of misreporting are correctly estimated, these results suggest that the current ICA assessment using reported catch is potentially giving misleading levels and trends of both SSB and fishing mortality.

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Appendix 1: R code for the catch sensitivity analysis

```
# Perform assessments of North East Atlantic Mackerel stock using the FLICA pack-
age.
# Examine sensitivity to historic catch levels
#
# Authors: David Miller, Thomas Brunel (John Simmonds)
#
# Developed with:
# - R version 2.8.1
# - FLCore 3.0
# - FLICA, version 1.4-10
# - FLAssess, version 1.99-102
# - FLSTF, version 1.99-1
# - FLASH, version 2.0
# - FLEDA, version 2.0.0
# Changes:
#
==========================================================================
### Initialise system, including convenience functions and title display
###
==========================================================================
rm(list=ls()); gc(); graphics.off(); start.time <- proc.time()[3]
options(stringsAsFactors=FALSE)
FnPrint <- function(string) {
cat(string)
flush.console()
}

require(FLCore)
require(FLICA)
require(FLAssess); require(FLSTF); require(FLASH); require(FLEDA);

# Uses the common HAWG FLICA Assessment module to do the graphing, diagnos-
tics and output
#where<-"D:/WGWIDE/WGWIDE2012/R assessment"
where<-"D:\\Work\\ICES\\WGWIDE\\WGWIDE 2013\\Mackerel\\Catch sensi-
tivity"
source(paste(where,"/source/HAWG Common assessment module change summary
plot.r",sep=""))

# Define parameters for use in the assessment code here
setwd(where)
data.source <- file.path(where,"data") #Data source, not code or package source!!!
```

```
output.dir <- file.path(".","2013 spe request") #Output directory - some questions re-
garding use old "res" or "results"
# these next two lines are stock specific - others are standar across stocks
output.base <- output.dir
#output.base <- file.path(output.dir,"NEAMac Catch Sensitivity") #Output base file-
name, including directory. Other output filenames are built by appending onto this
one

###
==========================================================================
### Prepare  objects for assessment
###
==========================================================================

#control
NEA.Mac.ctrl<-FLICA.control(sep.nyr=12,sep.age=5,sep.sel=1.5,sr=FALSE,
lambda.yr=c(1,1,1,1,1,1,1,1,1,1,1,1),
lambda.age =c(0.0033333, 0.033333, 0.33333,
0.33333, 0.33333, 0.33333, 0.33333, 0.33333, 0.33333, 0.33333,0.33333,0.33333,0.33333),
lambda.sr=0.01,index.model=c("l"),index.cor=0)

#stock
NEA.Mac <- readFLStock(file.path(data.source, "index.txt"),no.discards=TRUE)
units(NEA.Mac)[1:17] <- as.list(c(rep(c("Tonnes","Thousands","Kg"),4), rep("NA",5)))
range(NEA.Mac)[c("minfbar","maxfbar")] <- c(4,8)
NEA.Mac <- setPlusGroup(NEA.Mac,NEA.Mac@range["max"])
NEA.Mac@name <- "NEA Mackerel"
NEA.Mac@stock.wt[2,37:40]<-c(0.071,0.071,0.071,0.071)
#save the original NEA.MAc
NEA.Mac.origin<-NEA.Mac

#index
read.SSB.Index<-function(file.str,catch){
aa <-scan(file=file.str,skip=3)
aa <-t(matrix(aa,c(3,as.integer(length(aa)/3))))
dmns <-dimnames(catch)
dmns$year<-as.character(aa[,1])
SSB <-as.FLQuant(aa[,3],dimnames=dmns)
SSB <-FLIndex(index=SSB)
SSB@type <-"biomass"
return(SSB)
}

NEA.Mac.indices <-read.SSB.Index(paste(data.source,
"/Ssb.txt",sep=""),NEA.Mac@catch)
```

```
NEA.Mac.tun=FLIndices(NEA.Mac.indices)
NEA.Mac.tun[[1]]@index.var[] <- 0.1 # implies a weighting of 10 which was chosen in
2007 Benchmark
NEA.Mac.tun[[1]]@effort[] <- 1 # just a standard number - realy ignored if 1
NEA.Mac.tun[[1]]@index[NEA.Mac.tun[[1]]@index==0] <- NA
NEA.Mac.tun[[1]]@type <- "biomass"
names(NEA.Mac.tun) <- "NEA.Mac Egg Survey" #MPA: Added so that your graphs
are a bit prettier

###
==========================================================================
### Prepare catch misreporting ranges
###
==========================================================================
years <- ac(1972:2011)
misrep <- ma-
trix(NA,nrow=2,ncol=length(years),dimnames=list(c("min","max"),years))

# High misreporting (Klondike era)
highPeriod <- ac(1972:1989)
misrep["min",highPeriod] <-   1.7
misrep["max",highPeriod] <-   3.6

# High misreporting (Japanese market)
medPeriod <- ac(1990:2000)
misrep["min",medPeriod] <-    1.7
misrep["max",medPeriod] <-    2.5

# Low misreporting (g6 law implemented in Norway)
lowPeriod <- ac(2001:2005)
misrep["min",lowPeriod] <-   1.1
misrep["max",lowPeriod] <-   1.7

# Present time (low level slippage and discarding)
goldenYears <- ac(2006:2011)
misrep["min",goldenYears] <- 1
misrep["max",goldenYears] <- 1.1

# Account for changes in water reduction (assuming that 2% actually is water)
#(1972-1986: ?); 1986-1999:                    10% ; 2000-2003:            13% ; 2004- :
                              2%
waterRed <-
c(rep(1,length(1972:1985)),rep(1.08,length(1986:1999)),rep(1.11,length(2000:2003)),rep(
1,length(2004:2011)))
misrep <- sweep(misrep,2,waterRed,"*")
```

```
# Vector of possible misreporting/slippage by age
ageMisRep <- matrix(data=c(1.5,1.3, 1.3, 1.2, 1.1, rep(1,8)))
# Normalise
#ageMisRep <- length(ageMisRep)*ageMisRep/sum(ageMisRep)

###
========================================================================
### Loop over assessment
###
========================================================================
numIts <- 100
STF <- F
catSenRes <- list()
catchMult<-list()
Catches<-list()
Catches.n<-list()
Ns<-list()
Fs<-list()
catSenSTFRes <- list()
for (it in 1:numIts) {
cat("\n",it,"\n")
# Get original stock object
NEA.Mac<-NEA.Mac.origin
# Get annual misreporting values
tmpMisRep <- FLQuant(NA,dim=c(1,length(years),1,1,1,1));
dimnames(tmpMisRep)[[2]] <- years;
for (yr in years) tmpMisRep[,yr] <- runif(1,misrep["min",yr], misrep["max",yr])
 catchMult[[it]]<-tmpMisRep
# Adjust catch and catch at age
catch(NEA.Mac) <- catch(NEA.Mac)*tmpMisRep
catch.n(NEA.Mac) <- sweep(catch.n(NEA.Mac),2,tmpMisRep,"*")

# Include age dimension (comment out if not used)
tmpAge <-  as.FLQuant(ageMisRep %*% t(as.matrix(as.numeric(tmpMisRep))))
dimnames(tmpAge)[[2]] <- years; dimnames(tmpAge)[[1]] <- c(0:12)
catch.n(NEA.Mac) <-  catch.n(NEA.Mac) * tmpAge
#for (a in 1:12) for (y in years) catch.n(NEA.Mac)[a,y] <-  catch.n(NEA.Mac)[a,y] *
tmpAge[a,y]
# Correct for SOP
Sop <- as.numeric(catch(NEA.Mac)) /
as.numeric(colSums(catch.n(NEA.Mac)*catch.wt(NEA.Mac),na.rm=T))
catch.n(NEA.Mac) <- sweep(catch.n(NEA.Mac),2,Sop,"*")

Catches[[it]] <- catch(NEA.Mac)
```

```
==========================================================================
### Perform the assessment
###
==========================================================================

#Now perform the asssessment
NEA.Mac.ica <- FLICA(NEA.Mac,NEA.Mac.tun,NEA.Mac.ctrl)
#  replace the recruitment value in the last year by the geometric mean of recruitment
over the period 1972 to two year before assessment year
nyears<-dim(NEA.Mac.ica@stock.n)[2]
NEA.Mac.ica@stock.n[1,nyears]<-prod(NEA.Mac.ica@stock.n[1,1:(nyears-
2)])^(1/(nyears-2))
# do the same for the survivors
NEA.Mac.ica@survivors[1,]<-prod(NEA.Mac.ica@stock.n[1,1:(nyears-2)])^(1/(nyears-
2))
# recalculate age 1 for the survivors given the new recruitment for the last year and
the fishing mortality
NEA.Mac.ica@survivors[2,]<-NEA.Mac.ica@stock.n[1,nyears]*exp(-
NEA.Mac.ica@harvest[1,nyears]-NEA.Mac@m[1,nyears])
# put assessment results in stock object
NEA.Mac <- NEA.Mac + NEA.Mac.ica
# calculate total stock biomass for use in outpurt tables
NEA.Mac@stock=computeStock(NEA.Mac) # to get TSB in stock slot
# set flagged index resituals set to -99 as missing residuals to 0
NEA.Mac.ica@index.res[[1]]@.Data[NEA.Mac.ica@index.res[[1]]@.Data==-99] <- NA

# Save
# Only actually need Catch at age, N at age and F  at age matrices
Catches.n[[it]] <- catch.n(NEA.Mac.ica)
Ns[[it]] <- stock.n(NEA.Mac.ica)
Fs[[it]] <- harvest(NEA.Mac.ica)
## (but probably should check some diagnostics too, so save all)
#catSenRes[[it]] <- NEA.Mac.ica


###

res<-list(Catches,Catches.n,catchMult,Ns,Fs)
names(res) <-c("catches","catch.n","catchMultiplier","stock.n","harvest")

save(res,file="runAges.Rdata")
```

ANNEX 04 Stock Data Problems Relevant to Data Collection - WGWIDE

Stock	Data Problem	How to be addressed in	By who
Northeast Atlantic Mackerel	*Submission of data*	*Data submissions must* *Be submitted by the deadline* *Be submitted on the exchange format sheet* *Be submitted directky to the stock coordinator or, if uploaded to Sharepoint, the stock coordinator muct be notified* *In addition, should the data submitter change the stock cordinator MUST be notified of this. Also, should the data submitter be unavailable after the data has been submitted (e.g. vacation) an alternative contact should be avaialble who can be contacted in the event of any queries.*	*National laboratories*
Northeast Atlantic Mackerel	*Discardand slippage information*	*Discardand slippage information is incomplete. All fleets should be monitored and sampled for discard and slipping. Data should be supplied to the coordinator by the submission deadline, accompanied by documentation describing the sampling protocol.*	*National laboratories, RCMNA, RCMNS&EA*
Northeast Atlantic Mackerel	*Sampling deficiencies– general*	*All countries involved should provide sampling information. Increased cooperation between countries would help reduce redundancy and increase coverage.* *There is a particular lack of sampling coverage of the freezer trawler fleet in quarter 4.*	*National laboratories, RCMNA, RCMNS&EA*
Northeast Atlantic Mackerel	*Sampling deficiencies– stock weights*	*Stock weights for the western component are obtained from samples in areas VIIbcjk in March-May. In recent years sampling for stock weight has been insufficient. Additional targeted sampling effort is required by the appropriate countries.*	*National laboratories; RCMNA, RCMNS&EA*
Northeast Atlantic Mackerel	*Sampling of foreign vessels*	*Any information available from the sampling of foreign vessels should be forwarded to the appropriate person in the national laboratory in order that they may use this information when compiling the data submission.*	*National laboratories; RCMNA, RCMNS&EA*

Stock	Data Problem	How to be addressed in	By who
Boarfish	*Lack of sampling and age data.*	Following the MoU between ICES and EU boarfish (*Capros aper*) was included into WGWIDE. Sampling data are still only very limited accessible. Therefore boarfish should be included in the list of DCF species.	*PGCCDBS, RCMs, EU*
Boarfish	*Boarfish only measured to the 1 cm on the IBTS.*	Following the MoU between ICES and EU boarfish (*Capros aper*) was included into WGWIDE. Boarfish should be measured to the 0.5 cm on the IBTS due to the small length range and the relatively high ages observed.	*ICES IBTSWG*
Boarfish	Large proportion of *2012 Danish Boarfish samples only measured to the 1 cm*	Boarfish should be measured to the 0.5 cm due to the small length range and the relatively high ages observed.	*Danish National Institute*
Boarfish	*Third year of the acoustic survey funded by levy on the Irish and Danish industry.*	Following the MoU between ICES and EU boarfish (*Capros aper*) was included into WGWIDE. The Acoustic survey needs to be continued annually and should be considered under the DCF.	*PGCCDBS, EU, ICES SSGESST*
Horse Mackerel – Western Stock	*Uncertainties in the use of the current egg production method for the assessment*	Evaluation of the assessment model based on egg production and fecundity	*Future Benchmark*
Horse Mackerel – Western Stock	*Discard Information*	*Discard information is incomplete. All fleets where discarding is thought to be occurring should be sampled for discard. Data should be supplied to the coordinator accompanied by documentation describing the sampling protocol.*	*National Institutes, RCM NA*
Horse Mackerel – North Sea Stock	*Low level of sampling and survey data. Currently only IBTS data are available which are not entirely suitable for pelagic species*	Collection of information from other working groups. Possible implementation of an acoustic survey for horse mackerel in 3rd or 4th Quarter.	*PGCCDBS, RCM NS&EA*
Norwegian Spring Spawning Herring	*Contrasting age distributions between laboratories in the May survey*	It is recommended that a workshop on age reading is required for NSS herring to address discrepancies across nations, encountered during the recent May surveys.	*PGCCDBS*

Stock	Data Problem	How to be addressed in	By who
Norwegian Spring Spawning Herring	*Low sampling effort on some nations (considerably lower than the 1 sample/1000 tonnes recommended for this stock by EU)*	Sampling effort should be increased by nations with little or no samples.	*National laboratories; RCM NS&EA*

Annex 05 Assessment Audits

Audit of Northeast Atlantic Mackerel

Date September 2013

Reviewer: **Patrícia Gonçalves, Eydna í Homrum, Lisa Readdy**

For the attention of: Advisory drafting group, ACOM and WGWIDE

General

The assessment and short term forecast of **Northeast Atlantic Mackerel** was based on data handling procedures and assessment modeling as described in the last benchmark assessment carried out in 2007. This year the assessment was considered not appropriate for providing catch advice, the reasons behind this decision are described below. The EG concluded that the advice for 2014 should be based on the methodology described by the data limited approach category 3.2.0.

- Inclusion of new data produces an unrealistic estimate of the 2012 recruitment, around 100 times greater than that seen historically.
- Assumptions of the current model are violated, the possibility of changes in fishing practices during the separable period of 12 years, underestimation of catches by an unknown variable proportion.
- Only one non-age based independent tuning index available, collected every three years from an egg survey.
- Some of these concerns have been identified by the EG in previous years, whereas other became apparent this year.

For single stock summary sheet advice:

1) **Assessment type:** Update.
2) **Assessment**: Analytical, Integrated catch at age (ICA) in the FLR environment.
3) **Forecast**: None, no accepted assessment this year.
4) **Assessment model**: ICA tuned by ICES Triennial Mackerel and Horse Mackerel Egg Survey series.
5) **Data issues:** Catches reported for 2012 and in previous year are considered to be best estimates.
    - Estimates of discarding or slipping are either not available or incomplete for most countries.
    - Confidential information suggests substantial under-reported landings for which numerical information is not available.
    - Weight-at-age in the stock used in the assessment has been calculated using a very small number of samples in the most recent years.
    - Lack of age-disaggregated survey data.
    - Lack of annual survey data.

- o 2013 egg survey data is still preliminary.

6) **Consistency**: The assessment consistent with the 2012 assessment was not accepted by the EG. The advice for 2014 is based on the data limited approach category 3.2.0 using the ICES Triennial Mackerel and Horse Mackerel Egg survey series.
7) **Stock status**: The egg survey index shows a consistent increase in SSB since 2004, which is also supported by the increasing abundance and extending distribution of mackerel in summer observed on the IESSNS survey in the Nordic Seas since 2009. However there is insufficient information to compare the level of SSB with precautionary reference points.
8) **Man. Plan.**: There is currently no agreed management plan. (is this correct? As I understand the Stock Annex, the countries agree on the management plan per se – but because of other disputes it is not presently in action…. I may be wrong, however).

General comments

This review has taken place prior to completion and acceptance of the EG report and advice. The analytical assessment was updated and a number of sensitivity runs carried out. Due to the potential violation of the model assumptions the EG agreed to re-categories this stock under the data limited approach as a category 3 stock. The methodology used was a hybrid of that described by WKLIFE2 data limited approach, as only a triennial egg survey is available for this stock.

Technical comments

Figure 2.2.2.1 referred to in the text is missing from the figures section.

No reference in the text to table 2.1.2.1. Catches in tones of *Scomber colias* in Dvisions VIIIb, VIIIc and IXa in the period 1982 – 2012.

Table 2.3.1.1: A table in two sections – the second sections is a copy of the first section.

Tables 2.6.9-2.6.11 seem to have been inserted, but these are not referred to in the text. As a consequence, references to the subsequent tables in this section are wrong.

Egg production index: Stock annex describes procedure using temperature at 5 m depth (section B.3.1 – last paragraph), whereas the report uses water temperature at 20 m depth (section 2.5.1.1 – first paragraph).

(specific errors regarding data, figures, analyses etc.)

Conclusions

The decision to re-categories this stock under the data limited approach to category 3 was justified given the model violations and data uncertainties. The EG agreed to abandon the use of the current ICA assessment on the mackerel advice. This stock is scheduled to be benchmarked in the early part 2014.

Checklist for review process

General aspects

- Has the EG answered those TORs relevant to providing advice?

  YES – based on last year's assessment and data limited approach category 3.2.0.

- Is the assessment according to the stock annex description?

  YES – but not accepted by the EG

- Is general ecosystem information provided and is it used in the individual stock sections?

  YES

- If a management plan has been agreed, has the plan been evaluated?

  No agreed management plan.

For update assessments

- Have the data been used as specified in the stock annex?

  YES

- Has the assessment, recruitment and forecast model been applied as specified in the stock annex?

  Update of the analytical assessment not accepted by the EG.

- Is there any **major** reason to deviate from the standard procedure for this stock?

  YES – for reasons given above

- Does the update assessment give a valid basis for advice?

  No – analytical assessment not accepted by the EG

Audit of North Sea Hores Mackerel: Divisions Iva (1st and 2nd quarter), IIIa (excluding Western Skagerrak in 3rd and 4th quarter), IVb, IVc and VIId in 2013

Date: September 18. 2013

Reviewers: **Anna Olafsdottir, Faroese Marine Research Institute, and Are Salthaug, Institute of Marine Research, Norway.**

For the attention of: Advisory drafting group, ACOM and WGWIDE

General

The assessment and suggested advice is based on the ICES Data-limited approach (Category 3, Method 3.2); adjusting the catch (last three year average) by the ratio of the last two survey years estimates vs the previous 3.

For single stock summary sheet advice:

1) **Assessment type:** update
2) **Assessment**: Category 3 of the ICES Data-limited approach (DLS)
3) **Forecast**: none
4) **Assessment model**: Input data in the DLS approach: IBTS Q3 indices of fishable biomass (2008-2012), total landings data (2010-2012)
5) **Data issues:**
6) **Consistency**: The 2012 advice was based on the DLS approach utilizing IBTS survey data and landing information. One relative biomass index was calculated for horse mackerel > 20 cm. In previous years, three biomass indexes were calculated for different length groups of fish.
7) **Stock status**: unknown
8) **Man. Plan.**: Currently there is no agreed management plan.

General comments

This was mainly a well documented and well written section. Specific comments:

- It is stated that the sampling of catches/landings generally is too poor for an age-based assessment (e.g. only one fleet sampled during 1987-1995 and generally low sampling coverage). However, no analysis is presented on this. Perhaps a bubble plot and a within-cohort consistency plot of the catch at age matrix would have shown that year classes cannot be reliably tracked?
- More information about how the IBTS cpue index is calculated should have been presented or cited with a reference, e. g. what are the steps from trawl hauls to numbers at length indices. The description of how the indices of exploitable biomass were derived from numbers at length indices are, however, good.

- The reviewers feel that some of the information presented in the report is a bit to detailed/redundant: catch number at age, mean weight at age and mean length at age by quarter and area in 2012 (Tables 4.4.1.1, 4.4.2.1 and 4.4.2.2).
- Figures and Tables are not always correctly referenced in report text.

Technical comments

Calculations were performed as described in section 4.5 (Basis for 2013 Advice) and the same numbers were obtained.

Conclusions

This DLS based assessment is a good basis for advice.

Audit of Norwegian Spring Spawning Herring

Date September 2013

Reviewer: **Pablo Carrera, Gersom Costas**

For the attention of: Advisory drafting group, ACOM and WGWIDE

General

The assessment and short term forecast of **Norwegian Spring Spawning Herring** in the NE Atlantic is based on data handling procedures and assessment modeling as described in last benchmark in 2008 with some exception described below.

- From 2010 onwards, new maturity-at-age information was used for the whole time-series
- In 2013, an updated algorithm was used to derive the terminal fishing mortalities on the oldest age groups in the assessment for cohorts where there is insufficient information to estimates these. This is equivalent to assuming a fixed selection at oldest age

The information used in the assessment is catch data and survey data from eight surveys. The analysis was restricted to the years 1988 – 2013, which is regarded as the period representative of the present production and exploitation regimes, and is presumed to be of main interest for the management.

Historically, the size of the stock has shown large variations and dependency on the irregular occurrence of very strong year classes. But it is assumed that future recruitment patterns are similar as observed in the past.

A deterministic short term projection is used .

For single stock summary sheet advice:

1) **Assessment type:** update
2) **Assessment**: Analytical
3) **Forecast**: short term forecast presented
4) **Assessment model**: VPA (TASACS toolbox) tuning by 8 surveys series (Norwegian acoustic survey on spawning grounds in Feb./Mar. (NASF), Norwegian acoustic survey in Nov./Dec. (NASN), Norwegian acoustic survey in Jan. (NASJ), 2 International ecosystem surveys in the Nordic Seas (IESNS), 2 Ecosystem surveys in the Barents Sea (Eco-NoRu-Q3 (Aco)), Norwegian herring larvae survey on the Norwegian shelf (NHLS))
5) **Data issues:** Catch in tonnes, catch at age, weight at age in catch and in stock, natural mortality, proportion fishing mortality before spawning, proportion natural mortality before spawning, proportion mature at age, tuning fleets (8 surveys)
6) **Consistency**: the assessment of 2013 is consistent with last year's assessment.

7) **Stock status**: SSB is well above B_{PA} while F is well below F_{PA}. The current $F_{2\text{-}6}$ of 0.23 is in the range of plausible F_{MSY} candidates (0.2-0.3).

8) **Man. Plan.**: Management plan agreed agreed by the EU, Faroe Islands, Iceland, Norway, and Russia in 1999. The management plan aims to constrain harvesting within safe biological limits and is designed to provide sustainable fisheries in the long term. But in 2013 a lack of agreement on their share in the TAC has lead to unilateral set quota's.

General comments

(overall comments on how the assessment was conducted)

Change in maturity-at-age contributes to the change in perception of estimated SSB in the 2010 and later assessments compared to previous assessments

This new updated algorithm reduces the uncertainty in the assessment, as it makes it more robust to the noise caused by small year classe.

There are indications that there are changes in the catchability of herring in tuning survey (feeding area survey in the Norwegian Sea in May). These changes would produce bias in the results of the assessment. Studies on change of catchability of herring in the survey are required.

Currently is observed a decline in the stock. But the lack of agreement on share TAC will accelerate the present decline

Technical comments

The Figure 7.7.2.12 in text should be referred as 7.7.3.2.12

Is the figure 7.7.3.1 a final result?

In section 7.7.5, referred Figure 7.7.3.2.7 should be fig. 7.7.3.2.9

In section 7.11.1, referred Figure 7.7.3.2.2 should be fig. 7.7.3.2.12

No reference in the text to table 7.7.2.1

Conclusions

This assessment with forecast is a good basis for advice

Checklist for review process

General aspects

- Has the EG answered those TORs relevant to providing advice?

  YES/NO

- Is the assessment according to the stock annex description?

  <u>YES</u>/NO

- Is general ecosystem information provided and is it used in the individual stock sections?

  YES/<u>NO</u>

- If a management plan has been agreed, has the plan been evaluated?

  <u>YES</u>/NO

For update assessments

- Have the data been used as specified in the stock annex?

  YES/<u>NO</u>

- Has the assessment, recruitment and forecast model been applied as specified in the stock annex?

  YES/<u>NO</u>

- Is there any **major** reason to deviate from the standard procedure for this stock?

  <u>YES</u>/NO

- Does the update assessment give a valid basis for advice?

  <u>YES</u>/NO

Audit of Boarfish in the Northeast Atlantic

Date 17/09/2013

Reviewer: **Beatriz Roel and Mark Payne**

For the attention of: Advisory drafting group, ACOM and WGWIDE

General

The assessment and short term forecast of **boarfish in the NEA** is based on data handling procedures and assessment modeling as described in WGWIDE 2013 Report. In 2013 the advice is based on the results of a Schaefer surplus production model and follows the MSY approach. In 2012, the advice was based on the 2012 acoustic biomass survey estimate and an F_{MSY} proxy. In 2011, the advice was based on average catches in 2008–2010.

For single stock summary sheet advice:

1) **Assessment type:** benchmark
2) **Assessment**: analytical
3) **Forecast**: presented (short term) under Fmsy
4) **Assessment model**: Bayesian state-space surplus production, tuning by acoustic and bottom trawl survey series (SPPGFS, SPINGFS, IGFS, EVHOE and BFAS)
5) **Data issues:** assessment highly influenced by the acoustic surveys for which there are only two data points.
6) **Consistency**: This is the first analytical assessment presented for the stock.
7) **Stock status**: SSB is above B_{msy} = B_{PA} while F is below F_{msy}. There is large uncertainty around current estimate of biomass.
8) **Man. Plan.**: There is currently no agreed management plan

General comments

The assessment was conducted with scientific rigour. The statistical treatment of the input data was clearly presented and justified. The model chosen seemed appropriate given the data and sensitivity to assumptions was sufficiently explored.

Technical comments

The model was initially fitted to survey time series which were only represented a fraction of the stock but were treated as indices of total abundance. These indices were influential at providing a perception of historic stock development and its uncertainty which may be questionable. The WGWIDE Plenary agreed on removing one of the series and limiting the English survey data to the most recent period when most of the stock distribution overlapped with the survey area.

Conclusions

This assessment with forecast is a good basis for advice

Checklist for review process

General aspects

- Has the EG answered those TORs relevant to providing advice?

  YES

- Is the assessment according to the stock annex description?

  Stock Annex has not been presented yet

- Is general ecosystem information provided and is it used in the individual stock sections?

  YES

- If a management plan has been agreed, has the plan been evaluated?

  Management Plan proposed by the Pelatic RAC but not evaluated by ICES

For update assessments

Not applicable

Audit of Western Horse Mackerel in IIa, IVa, Vb, VIa, VIIa-c, e-k, and Subarea VIII (Western stock)

Date 02/09/2013

Reviewers: **Jens Ulleweit and Andrew Campbell**

For the attention of: Advisory drafting group, ACOM and WGWIDE

General

The assessment and short term forecast of **Western Horse Mackerel** in **IIa, IVa, Vb, VIa, VIIa-c, e-k, and Subarea VIII (Western stock)** is based on data handling procedures and assessment modeling as described in 2008 when the assessment was accepted by WGWIDE (separable window was increased to 6 years in 2009). The assessment has not been benchmarked.

For single stock summary sheet advice:

1) **Assessment type:** SALY
2) **Assessment**: analytical
3) **Forecast**: presented (short term)
4) **Assessment model**: SAD (Linked Separable Adapt VPA) tuning by 1 survey index (triennial egg survey) and 1 tuning index (potential fecundity vs fish weight 1987,1992,1995,1998,200,2001)
5) **Data issues:** stock weights (ages 0-2), lack of discard information. Lack of age-dis-aggregated survey data. Lack of annual survey data.
6) **Consistency**: The assessment seems to be consistent with the 2012 assessment.
7) **Stock status**: SSB is estimated to be at 0.84 Mt in 2013. F has been increasing since 2007 and is above Fmsy (0.19) since 2011. Recruitment has been low since 2004.
8) **Man. Plan.**: There is currently no agreed management plan.

General comments

The procedure is conducted according to the stock annex. Only available tuning data are based on a triennial survey which is designed for deriving the annual egg production of mackerel but is also used for estimating an egg production index for horse mackerel. Discard data are only available for parts of the fishing fleet, so the total amount cannot be calculated.

Technical comments

Catch data has been checked against the exchange sheets uploaded to WGWIDE2013 Sharepoint for this stock. Any discrepancies of >1t are detailed.

General comment: what do the symbols +,--,- and <blank> in tables 5.1.1.1-5 signify?

Table 5.1.1.3:

Irish catches should be 29,350t (missing VIb catch?)

It is unclear where the 2t unallocated/discards originates

Table 5.1.1.5:

French catches should total 1,218t.

No exchange sheet is available for Russia (7t in area VIII)

Spanish data has been recorded against UK (Eng & Wales)

Total catch from tables 5.1.1.1-5 = 66t + 3,321t + 44,975t + 104,098t + 17,402t = 169,862t yet the total WG catch in report section 5.1.1 is given as 173,142t

Table 5.2.8.1 – layout is unclear, what is the leftmost column displaying?

Figure 5.2.10.4 – difficult to distinguish between the lines for 2008/2009 and 2011/2012, especially for selection (no year axis)

Table 5.3.1.3 – footnote should reference recruitment in 2012, not 2011

Table 5.4.4 – missing (referenced from section 5.4 – short term forecast)

Report section 5.4 (short-term forecast) – final paragraph references $B_{trigger}$ and F_{MSY}, neither of which were described in the preceding paragraph/text table on reference points.

Conclusions

Procedures have been carried out in accordance with the stock annex. However, the assessment suffers from the lack of age information in the single available fishery-independent index. This results in a rescaling of the assessment every three years, when a new survey point becomes available and a revision of the reference points.

Checklist for review process

General aspects

- Has the EG answered those TORs relevant to providing advice?

  YES

- Is the assessment according to the stock annex description?

  YES

- Is general ecosystem information provided and is it used in the individual stock sections?

  YES.

- If a management plan has been agreed, has the plan been evaluated?

A plan proposed by the Pelagic RAC in 2007 was initially judged to be precautionary only in the short term. This plan was used to set the TAC until 2011. An objection to the use of the plan resulted in advice being derived from the MSY framework since 2012. Responding to a 2013 EC request to evaluate possible modifications of the plan, ICES considered the plan to be inconsistent with the PA approach because it is not robust to two or more years of low recruitment (which has since been observed). ICES was unable to advise on a suitable replacement plan until further work is carried out.

For update assessments

- Have the data been used as specified in the stock annex?

  YES

- Has the assessment, recruitment and forecast model been applied as specified in the stock annex?

  YES

- Is there any **major** reason to deviate from the standard procedure for this stock?

  NO

- Does the update assessment give a valid basis for advice?

  YES

Annex 6 Mackerel Advice for 2014 – Supporting Information

Supporting information for the decision on the advice for NEA Mackerel for 2014

Summary

- Indications are that the NEA mackerel stock is being exploited at a lower level than in the past and that stock size has increased in recent years despite increasing catches.
- Catch data for this stock are considered to be poor. The inclusion of such data in the current assessment would cause an unknown bias in the perception of the trends in abundance and exploitation.
- Both maturity at age and mean weight at age are poorly estimated for this stock (the maturity ogive is based on 1984, 1997 and 2000 data and weight at age is often based on limited sampling).
- At WGWIDE 2013 it was **agreed** to abandon the use of the ICA assessment (benchmarked in 2007) for the provision of advice for mackerel.
- It was **agreed** to place mackerel in Category 3 of the ICES Data Limited Stocks (DLS) guidelines.
- Advice cannot be provided on the basis of the management plan since there is no agreed assessment model on which to base such advice.
- The advice would be on the basis of Method 3.2, adjusting the catch (last three year average) by the ratio of the last two survey estimates vs the previous 3.
- The egg survey to be used is triennial (new data point every three years), so linear interpolation was needed. However, the advice is not sensitive to the method used to adjust catches on the basis of the survey.
- There was **no clear agreement** in the group as to whether or not a precautionary buffer should be applied to the advised TAC. There are numerous arguments for and against the application of such a buffer.
- If the assumption that catch reporting has improved since 2005 is not true, some conclusions about the suitability of the model and the perception of recent exploitation could be incorrect.

ACOM is strongly advised to take all the relevant arguments presented below into account when drafting the advice for this stock.

Background

At the 2013 WGWIDE meeting the decision was made to abandon the ICA stock assessment model previously used to provide advice on the exploitation of the NEA mackerel stock (benchmarked six years ago; ICES 2007). This decision was made following open plenary discussion. Concerns over the use of this model mainly revolve around the quality and selection of data inputs and the model's ability to appropriately handle these data. These concerns have existed for a number of years, and in fact the option of abandoning the model was seriously considered at WGWIDE 2012 as well. The result of this decision is that advice for NEA mackerel will now come from the ICES data limited stocks (DLS) approach (ICES 2012).

In addition to carefully explaining the rationale for abandoning the ICA model, it is necessary to decide which category of the DLS approach applies to mackerel and whether or not a precautionary buffer should be applied to the advised catch level. It is also important to clearly describe the appropriate management considerations that arise from this change in the basis of advice, as well as the future steps that will be taken to ensure that the best possible knowledge and data are used in an integrated way to provide advice for this valuable and ecologically important stock in the future.

Data used in the assessment of the stock

Catch data

The reported catch data for NEA mackerel is considered an underestimate due to limited accounting for discarding, slippage, and illegal, unregulated, and unreported (IUU) catches (ICES 2006, Simmonds et al. 2010, mackerel fishing industry (WKNAMMM) *pers comm.*).

Estimates of discards from Dutch freezer trawlers over the period 2003-2012 indicatean additional 16-37% of removals in addition to the landed catches. However, discarding rates are likely to vary between fleets and observer coverage of the fleets fishing for mackerel has never been complete. Slippage, because of mixed catches or excess catch, is a challenge to estimate regardless of the presence of observers. In Scotland, discrepancies between official declared landings and the tonnages reported as processed by the factories were found to be large (factor of 1.6, ICES 2006). An analysis of Irish export figures estimated an overquota factor of 1.7 for the period 1988–2002 (Remøy et al. 2003), though these findings were strongly contested (Marine Times 2003). It is standard practice to subtract a certain percentage of the landed weight of mackerel as water. In the past this water content percentage has varied substantially between countries and years and has been as high as 10-15%. Since 2003 this has been fixed to 2 % by a EU directive and agreement with Norway. Thisa would lead to a relative underreporting of actual landed mackerel for the period prior to 2003 compared to present reported landings.

In addition to these estimates of underreporting, anecdotal information exists that suggests past reported catches are an underestimate. For example the "Klondyking period" (uncontrolled delivery of mackerel catches to large Eastern European factory vessels offshore making the fishery virtually unregulated) and suspected highgrading due to significant size dependent differences in prices from the Japanese market during the 1990s. Since 2005 the discrepancy between official landing statistics and the true removals is believed to be relatively low compared to the earlier period described.

Simmonds et al (2010) found that to reconcile mortality estimated from the different fishery independent datasets for the period up to 2007, the landings and discards reported would have to have been between 1.7 and 3.6 times higher than the recorded catches. However, it is not possible to reconstruct exact values or estimates from the past.

Egg survey

The mackerel egg survey has provided an SSB estimate for the stock on a triennial basis since 1992. The spatiotemporal coverage of the survey differs over time in an attempt to ensure that the majority of the spawning area of mackerel is sampled. Estimates of the spawner stock biomass are calculated on the basis of egg abundance, fecundity estimates, sex ratio and % atresia occurrence. The Working Group on Mackerel and Horse Mackerel Eggs Surveys (WGMEGS; ICES 2013b) has always considered the egg survey to be an underestimate due to the fact of the non-accounting of the stage 1 egg mortality and potential missing spatial and temporal coverage. The benchmark assessment recommended treating the egg survey as indicative of trends in SSB, not as an absolute estimate of SSB.

The most recent survey was conducted in 2013. Even though the survey planning had taken into account an apparent trend in earlier spawning of mackerel, the temporal spawning peak may not have been sufficiently covered by the egg surveys (i.e. spawning likely occurred before the start of the egg survey). The results from this survey are still preliminary and it is not possible to predict if there will be changes to the preliminary results (final results due in April 2014).

Since 2004, egg survey SSB estimates have been increasing linearly at a rate of approximately 7% per year (doubling in size over 10 years). There are no other appropriate fishery independent indices over this whole time period with which to compare this perception of trend. However, the information provided by the egg index is consistent with other fishery independent data sets (e.g. swept area estimate from the IESSNS survey), fisher perception and expert knowledge. WGWIDE is confident that the stock has expanded in recent years both in size and in terms of geographical spread. All available indicators suggest this.

Biological information

Since the ICA assessment utilises an index of SSB, the model requires accurate estimates of maturity and weight at age in the stock (at least every three years). The maturity ogives (one per component) for this stock were derived in 1984, 1997 and 2000. The stock maturity ogive is a weighted average of these three constant ogives, recalculated every three years. In 2012 only one sample of 25 fish was available to estimate the mean weight at age for a stock of billions of widely distributed fish. In egg survey years more samples are available from research vessels (e.g. 666 fish in 2013). The egg survey samples have been applied to the year before the survey year as well as in the survey year. This is potentially problematic when trends in weight at age are observed. Both maturity at age and mean stock weight at age are poorly estimated for this stock.

The estimation of mean weight at age in the stock can, and will, be improved on at the WKPELA benchmark in February 2014. Weight at age data in January-February from EU-catches from west of the British Isles and Ireland have been sampled at Norwegian factories. There are also data from May since the start of tagging in 1969. Nevertheless, at the time of WGWIDE 2013, such data for the whole time series were not available to the group and the mean weights at age in the stock would have been estimated in the assessment as described above.

The ICA assessment model

The ICA assessment model consists of two main parts: a recent separable period and a VPA constructed past (Figure 1). These periods make two main assumptions when handling catch data. The VPA period assumes that catch at age estimates are exactly known. For the separable period, it is assumed that fishery selectivity at age is constant over the whole period (the last 12 years).

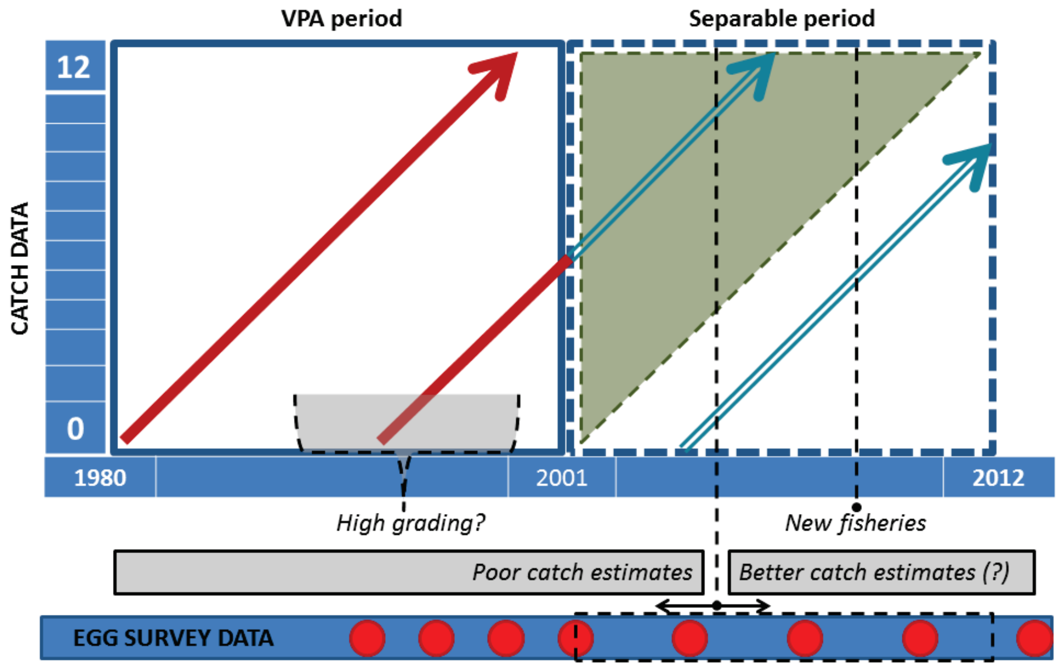

Figure 1. A schematic of the main features of the Integrated Catch at Age (ICA) model.

In Figure 1, the red arrow indicates a cohort where abundance and F estimates depend on the assumption of exact catch data, the hollow blue arrow indicate a cohort where these estimates depend on the assumption of constant selectivity, and the combination arrow indicates a cohort where these estimates depend on both assumptions. The grey shaded triangle indicates a selection of log catch residuals at age that are significantly smaller than the remaining residuals in the recent ICA fit to the data. This indicates that the selectivity pattern used in the separable period fits tighter to the cohorts that originate from the VPA period. This corresponds to a period where catch data are considered poor and there is strong potential that high grading occurred.

The assumption that catches are exactly known is one of the biggest criticisms of all VPA models, since this is very rarely considered to hold true. It is certainly not true in the case of mackerel. If the degree to which the catch at age estimates are wrong is constant over time, the trends coming out of a VPA assessment would still be acceptable. However, even this assumption does not hold true in the case of mackerel. Since the last benchmark, and the evaluation of the management plan, the consensus was that, assuming a constant proportion of unaccounted mortality, the SSB from ICA was indicative of the trend in the real SSB, and the estimate F was reliable. Unfortunately, simple catch sensitivity tests (Figure 2) show a potentially big, unpredictable impact on the assessment outputs. If catch data has indeed improved in recent years, estimates of historic F are likely to be largely unchanged but the degree to which the model overestimates F shows a trend since the improvement in catch reporting.

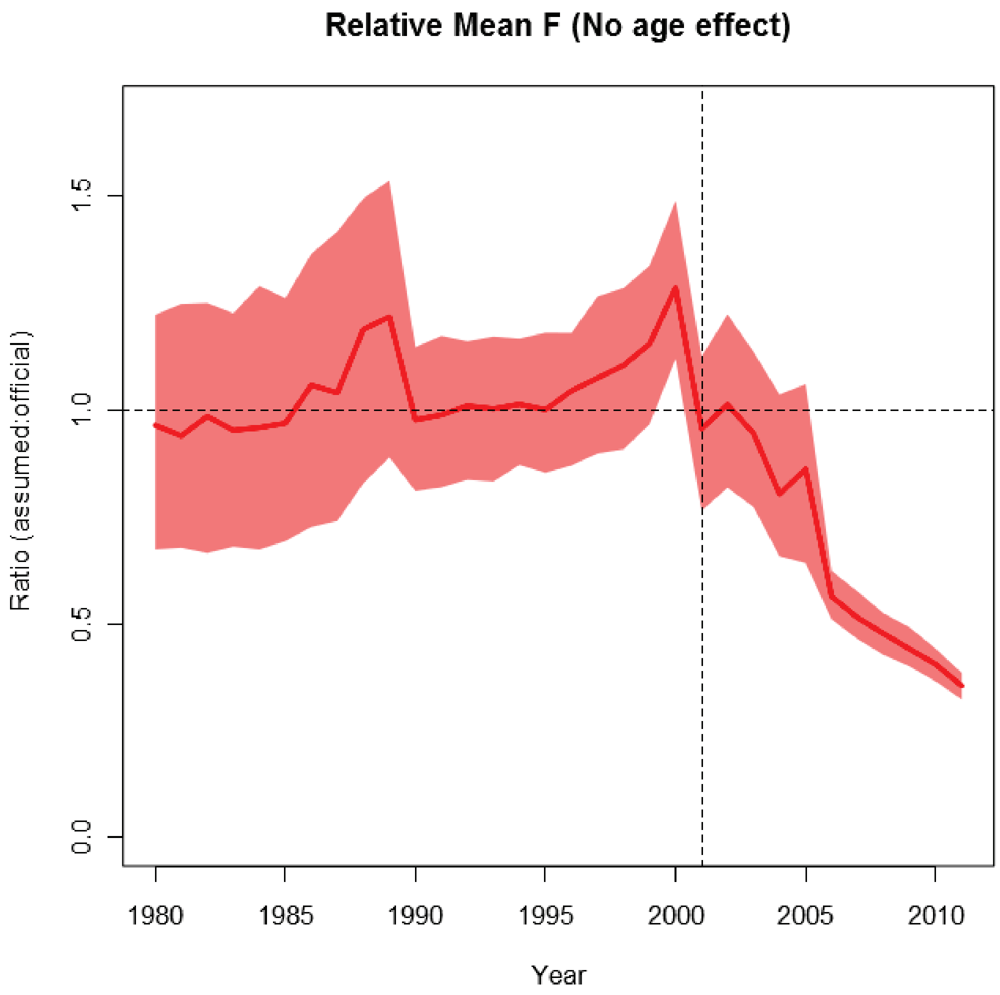

Figure 2. The ratio of ICA estimated F assuming underreported catch prior to 2005 and ICA estimated F using official reported catches.

The assumption of constant selectivity during the separable window is unlikely to be true for the mackerel fishery, which has changed significantly in the recent past. Over the last 12 years (the duration of the separable window), the expansion of the stock into new waters has lead to the introduction of new fishing fleets catching mackerel in new fishing areas. Catches in the northern areas (II, V, XIV) now form a greater proportion of overall catches. While these new fleets use similar gears to the other major fleets, they fish in a different area at a different time of the year when the fish are more disaggregated. Additionally catch reporting is assumed to have changed within the separable window. The perception of the selectivity at age would change if fewer young fish are discarded.

Three egg survey estimates were made during the VPA period of the model (Figure 1). Since the VPA period is incapable of producing an accurate estimate of stock size and trend with the given catch data, this has a knock-on effect into the separable period since the catchability model for the index will be influenced by how these three data points relate to the estimated stock size in the VPA period.

The nature of the catch data available does not adequately satisfy either of the assumptions the model makes when using this data. The only available fisheries independent index has a coarse temporal resolution. The poor catch data used in the assessment, leads to inappropriate estimation of catchability of the egg survey data by ICA. The mean weight at age of the stock, needed by the model for the calculation of SBB to compare with the index, is very poorly estimated. A wrong stock perception will also impact the forecast of the stock status impacting advice on future fishing opportunities. **Considering these points, WGWIDE decided that the model was an inappropriate basis for the provision of advice on this stock.**

This stock is due to be benchmarked in February 2014. We cannot at this stage predict the outcomes of this benchmark, but the group feels confident that a more reliable basis for advice will be possible following this meeting.

It should be noted that the benchmarked assessment applied to the available data at WGWIDE 2013 resulted in an anomalous, large, recruitment estimate in the final year and that various 'fixes' could have been applied to remove this. Although this anomaly is not unrelated to the problems outlined above, . the fundament violations of the assumptions needed to apply the ICA model to this data provide a far more valid basis for the rejection of the model.

What DLS category should it fit into?

Mackerel no longer falls under **category 1** (full analytical assessments and forecasts). Hence, advice cannot be provided on the basis of the management plan since there is no agreed assessment model on which to base such advice.

Category 2 includes stocks with quantitative assessments and forecasts which, for a variety of reasons, are merely indicative of trends in fishing mortality, recruitment, and biomass. The assumption is that the assessment estimates, their forecasts and status relative to reference points are consistent with each other. However, the potential trend in misreporting probably causes a violation of this. If misreporting had been constant over time, then category 2 could apply. The SSB trend showed by the ICA benchmark assessment from 2007 onwards is sensitive to the model assumptions on recruitment and was not consistent with the increasing trend in SSB showed by the both the egg survey and by other fishery independent indices. Hence mackerel does not fit into category 2 of the DLS.

Category 3 includes stocks for which survey indices (or other indicators of stock size such as reliable fishery-dependant indices) are available that provide reliable indications of trends in stock metrics such as mortality, recruitment, and biomass. The general concept of survey-based catch advice is based on the assumption that if catch exceeds biological production this will cause a reduction in the stock. Therefore, decreasing surveys suggest catch should be linearly decreased and vice versa. **WGWIDE considers that the egg survey estimates of SSB provided by WGMEGS are of sufficient quality to be used as a relative indicator of mackerel stock size. Therefore the group proposed that mackerel be placed in category 3 of the ICES DLS approach (Method 3.2).** Details of how the advice is derived from this index are provided in the WGWIDE report and the advice sheet for this stock.

Since Category 3 was considered appropriate, categories 4 and lower were not looked at. These would represent inferior options in any case.

ICES DLS guidelines (ICES 2012) requires the ratio from the last two years compared to the previous three. Since the egg survey is triennial, intermediate years were interpolated linearly from alternate egg survey values (Figure 3). This was done to increase conformity with the ICES DLS guidelines, but was not done without first considering a number of other approaches to using the recent egg survey data. Since the last four data points of the egg survey form a strong linear trend, it was not surprising that all rational methods for predicting future sustainable catch on the basis of this index resulted in similar levels of advised TAC. While uncertainties persist because of the triennial nature of the data, the actual method using this data does not have a significant effect on the resulting advice.

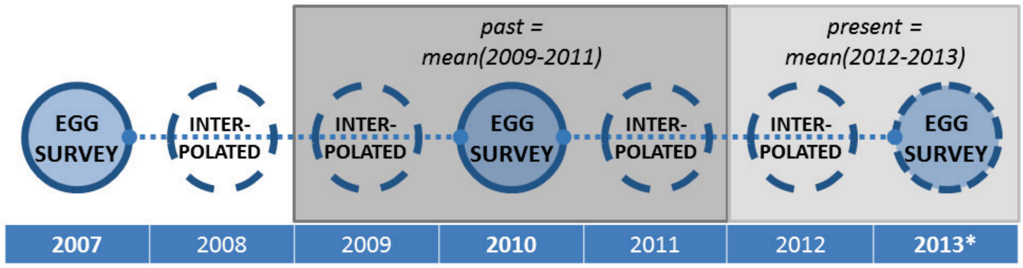

Figure 3. The application of the ICES DLS approach (method 3.2) to the mackerel egg survey index. The 2013 egg survey value is preliminary (until April 2014).

The 'increasing uncertainty – increasing advice' paradox

The natural result of using a categorization scheme that implicitly ranks the approaches to advice provision (as the ICES DLS scheme does) is that it is assumes that the lower the rank, the higher the uncertainty in the advice. In principle, in the absence of an assessment the DLS approach is supposed to provide increasing levels of caution to catch advice commensurate with the uncertainty. Moving NEA mackerel form Category 1 to Category 3 and increasing the advised catch, could be seen as contradictory to best practice. However, what moving down the ICES DLS scale actually implies is that less data are used. The data no longer used in this case are the highly uncertain catch estimates and very poorly estimated weights at age. When you stop using potentially biased, incorrect data sources, this in theory leads to less uncertainty.

Uncertainty has always existed in the advice previously provided using the ICA assessment. The message ICES has given in recent years was that "the current level of catches is not sustainable and will lead to a collapse". This was based on a forecast where 4 years (2010-2014) of recruitment were expected to be average, and based on a very uncertain estimate of 2010 recruitment (because of limited data for this cohort). Recent surveys (IESSNS) indicate that the assumption of average recruitment was likely wrong as the 2010 and 2011 year classes appear to be strong. Additionally, until 2013 the last fisheries independent estimate of biomass was from 2010.

Of course, using the egg survey also involves uncertainty. Each individual survey point has an associated CV (24% in 2010, 17% in 2007) and the 2013 survey value is still preliminary.

However, no management of large scale fisheries exploiting widely distributed, highly migratory stocks is free from uncertainty. In the case of NEA mackerel, the choice is: base the advice on an index of stock size that is believed to contain accurate information about trends in stock development (the egg survey) **or** use the same index together with an uncertain time series of catches and poorly estimated biological parameters whilst violating the assumptions of the modelling framework used to combine these data series.

Should we apply a precautionary buffer?

ICES DLS Guidelines

The ICES DLS approach includes the possibility of applying a 20% reduction to advised catch levels in certain cases. This is called the 'precautionary buffer' (previously the "precautionary margin"). A precautionary buffer of -20% has been applied for those cases when the stock status relative to candidate reference points for stock size **or** exploitation is **unknown**.

However, exceptions to this rule have been made. Following the ICES DLS guidelines (ICES 2012, ICES template for advice), no precautionary buffer is needed if **either of the following are true**:

1. Exploitation is not detrimental to the stock (F has a green tick mark)
2. Exploitation status is unknown (question mark for F), and the effort in the main fisheries has decreased significantly
3. Exploitation status is unknown (question mark for F), but biomass has increased by more than 50%
4. If substantial increases in abundance indices or other stock indices are **consistently** observed (i.e. not due largely to noise in the data)

In addition, not using the precautionary buffer could be supported if expert judgment determines that the stock is not reproductively impaired.

Point (1) implies that not only is exploitation rate known, but also the current level in relation to some reference point indicative of sustainable exploitation. However, other possible analyses could be used to give an indication of whether exploitation rate is increasing, stable or decreasing in recent times.

In some cases, e.g. Ling in Division Va, an F proxy (total catch/survey biomass) has been used to compare current exploitation to previously observed levels. In the case of Ling, the F proxy was calculated over a period of stock increase (2003-2007). The value was found to be in the lower range of observed values over a time period when no detrimental effects were observed in the stock dynamics, and was considered to be an appropriate advisory Fproxy upon which to base catch advice.

Figure 4 below (Mark Payne) shows the trend in such an F proxy calculated for mackerel. Both biomass (as evidenced by the egg survey) and catches have increased steadily since the mid-2000s. The quality of catch data since the mid 2000s is assumed to have increased and is thought to be more reliable than in the past. Catches prior to this time are unreliable, but are almost certainly an underestimate.

The F proxy (catches per egg survey) has remained relatively constant since 2007. Prior to this time, the proxy was markedly higher based on reported statistics, and was probably even higher still in reality (due to under reporting). The post-2007 period therefore appears to be a period of relatively low exploitation. That the population has increased while the proxy for exploitation rate has remained relatively constant suggests productivity of the population is greater than the removal rate. Given the excess productivity, and the relatively low historic exploitation rate, the stock does not show signs of overexploitation.

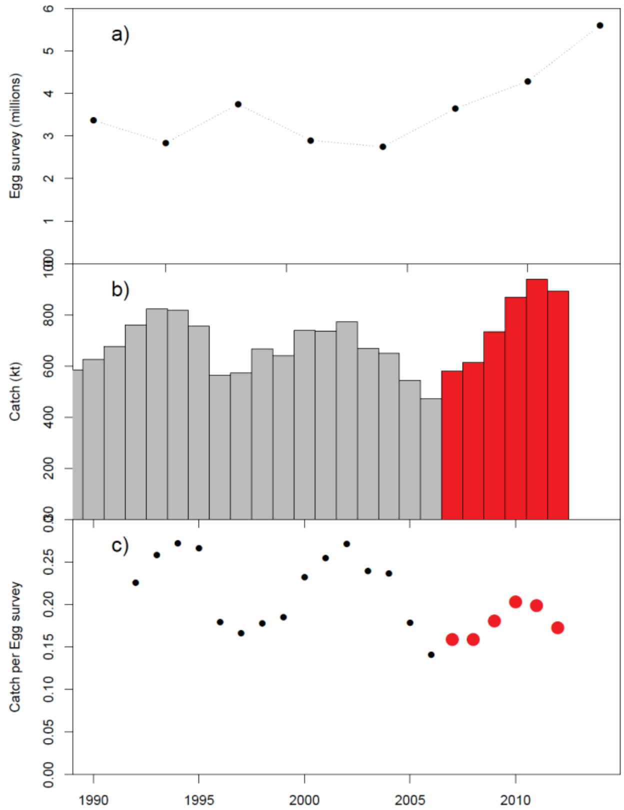

Figure 4. (a) Egg survey, (b) catch and (c) F proxy (catch/egg survey) values for 1990-2013.

Catch curve analysis (Figure 5 below, Thomas Brunel) could be used to provide estimates of the trend of exploitation in recent times. However, numerous concerns exist regarding the applicability of this type of analysis to the mackerel stock:

- Catch data prior to (at least) 2005 is considered unreliable.
- The estimated Z values for the most recent cohorts (some of which are already an important part of the fishery) cannot be calculated due to insufficient exploitable ages over which to calculate a slope.
- Selectivity at age may have changed over the time period of the analysis

Given these concerns, catch curve analysis for this stock cannot adequately provide information on the trend in **recent** exploitation.

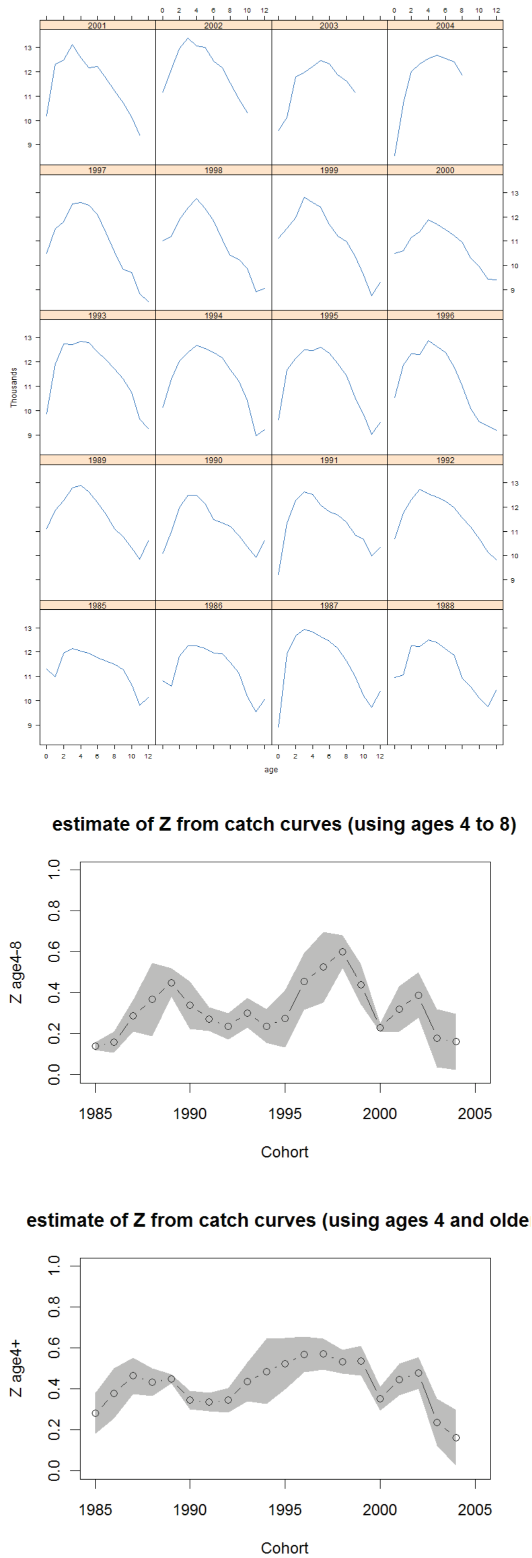

Figure 5. Catch curves and resultant estimated Z (negative log slope) values for alternative age ranges.

While WGWIDE agrees that the stock seems to have increased in spite of increasing catches since 2006, how current F compares to an estimate of long term Fmsy value is unknown. Hence, there is uncertainty over whether the stock is technically over- or under-exploited. However, in the short term (last 5 years) the stock was probably underexploited relative to the past, a period that did not lead to stock collapse.

Point (2) does not hold true in the case of mackerel. If anything, it is likely that effort has increased.

Point (3) does not state the time period to consider, but the ICES DLS guidance document defines it as:

$$\left(\frac{\sum_{i=y-2}^{y-1} I_i \big/ 2}{\sum_{i=y-5}^{y-3} I_i \big/ 3}\right) \geq 1.5$$

Calculating this from the egg survey index (including extrapolated values) gives a value of 1.23 (<1.5), and hence this point does not hold true in the case of mackerel. However, the egg survey used (the proxy for biomass in this case) has increased at a rate of around 7% per year since 2004. Compounding growth at this rate would take 6 years to get an increase of 50%. This rate of stock growth, and the long time period over which it is observed, could be argued to be a "consistent, substantial increase in abundance" according to **point (4)**.

Preliminary age-disaggregated indices from the swept-area estimations in IESSNS indicate that strong year classes (from 2010 and 2011) are joining the SSB in the coming years, suggesting the stock is not reproductively impaired.

The abundance of eggs and widespread spawning activity observed in the 2013 egg survey would suggest that the stock is not reproductively impaired. The Fproxy analysis suggests the stock is not being over exploited and the biomass index (egg survey) shows signs of consistent large growth in the stock. **These points suggest that the use of a precautionary buffer in the case of mackerel would be inappropriate.**

Additional precautionary considerations

The ICES DLS approaches calls for a precautionary approach to be followed. This implies that as information becomes increasingly limited a further margin of precaution should be adopted when the stock status is poorly known. Ultimately, the margin of risk tolerance is a management prerogative. By abandoning the analytical assessment, we have essentially acknowledged that there is a high degree of uncertainty over the degree of exploitation exerted on the mackerel stock. Despite the general conclusion in the section above, there was no consensus amongst members of WGWIDE to recommend that the precautionary buffer should not apply, many citing other general precautionary considerations that should be taken into account that support the use of a buffer:

1) The proposed category 3 advice is based on a single ?? the egg survey index with associated uncertainties.
2) Interpolation was required such that only 3 true data points are used (though 5 values are used in the HCR). The recent trend in SSB could be inappropriately estimated by the linear interpolation. However, since this

is a relatively long lived species, with potentially numerous recent good year classes, SSB is not likely to vary so much between years.

3) Of the three data points, only 2 are final values (a preliminary value for the 2013 index is used, and revisions up to 20% have been made in the past, though upwards for the last two estimates).

4) There is uncertainty on whether the recent exploitation level is sustainable in the long term (even though it might be in the short term).

5) We are also fairly sure that effort and catches have increased in recent years. Using 6 years of egg survey data in conjunction with only 3 of catch data is questionable, especially when the range of catches over the last 6 years is large.

6) We cannot say if the stock is in a high productivity regime without more information.

7) The decreasing trend in mean weight at age implies that more fish need to be caught per ton of advised TAC. This implies a higher F per ton. However, reduced weight at age is often a response to increased density resulting from a growing population.

8) The absence of clear international agreements among the Coastal States on the sharing of the TAC for NEA mackerel is a cause of continued concern as this prevents control of the exploitation rate of the stock. The actual exploitation on the stock has been higher than the advised level since 2010. This is primarily a management consideration, and not one that we as fisheries scientists have any control over.

9) A lot of the conclusions above about the suitability of the model and the perception of recent exploitation could be incorrect if the assumption that catch reporting has improved since 2005 is not true. Current estimates of slippage and discarding for the whole fishery combined are poor. In a situation where TACs are limiting and there is a growing stock with numerous recent strong year classes, the opportunities for highgrading are likely to increase. This could be the case over the last 3 years.

The assessment can be considered inappropriate, but using the egg survey in the ICES DLS advice does not come without uncertainty. Indications are that the stock is being exploited at a lower level than in the past and that stock size is increasing despite increasing catches. Advising higher catches is therefore not considered inappropriate for this stock. There are numerous arguments in favour of, and opposed to, the application of a precautionary buffer on the advised catch level. There is no consensus within WGWIDE as to the appropriate action in this case. It is important to remember that the degree of risk taken is primarily a management decision. ACOM is strongly advised to take all the relevant arguments presented above into account when drafting the advice for this stock.

Potential calculations of advice for NEA mackerel

For data limited stocks for which a biomass index is available, ICES uses an index-adjusted status-quo catch as a harvest control rule. The advice is based on a comparison of the two most recent index values with the three preceding values, combined with recent **landings** data.

Landings data

The working group uses an estimate of total catches for the assessment that includes the total reported landings as well as the reported discards. Discard estimates are only available for a small proportion of the fleet, so these are not considered to be complete. The text table below gives a brief overview of the basis for the working group catch estimates.

Country	Official Log Book	Other Sources	Discard Information
Denmark	Y (landings)	Y (sale slips)	Y
Faroe	Y (catches)	Y (coast guard)	NA[1]
France	Y (landings)		N
Germany	Y (landings)		Y
Iceland	Y (landings)		N
Ireland	Y (landings)		Y
Netherlands	Y (landings)	Y	Y
Norway	Y (catches)		NA[1]
Portugal		Y (sale slips)	Y
Russia	Y (catches)		NA[1]
Spain	Y	Y	Y
Sweden	Y (landings)		N
UK	Y (landings)	Y	N

[1]In the Russian, Norwegian and Faroese fleets discarding is illegal, which means officially landings are equal to catches.

The advice for 2014 is therefore based on the average of the last three year's **landings** (since there is no trend over this time period). No estimation is made of what this would lead to in terms of total catch.

The table below shows the landings and discard estimates for 2010-2012 (in t).

Year	Ldg	Disc*	Catch
2010	862,470	6,981	869,451
2011	929,807	9,012	938,819
2012	877,382	15,380	892,762

***Discards are poorly estimated for this stock**

The average landings for 2010-2012 = (862,470 + 929,807 + 877,382)/3 = 889,886 t

Index change

In the case of the NEA mackerel, for which the index is available every three years (the most recent being 2007, 2010 and 2013), linear interpolation was used to generate annual index values.

The interpolated preliminary SSB index in the last two years (2012–2013) is 23% higher than the average of the three previous years (2009–2011). Given that the increase is larger than 20% the uncertainty cap applies and the change in the catch is limited at 20%. Given that the recent catches are stable, the value of the status-quo catch was set at the average catch over the years 2010-2012.

Precautionary buffer

A precautionary buffer of 20% could be applied.

Advice

Following the ICES DLS approach (category 3.2), the advice for 2014 would be calculated as follows:

TAC_{2014} = (average landings 2010-2012) * (index change) * (precautionary buffer)

Therefore:

TAC_{2014} = 889,886 * 1.2 *0.8 = **854,291 t**

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